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TREATISE ON THE THEORY OF THE CONSTRUCTION OF HELICOIDAL OBLIQUE ARCHES.*

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II.

Chapter III.

OBLIQUE ARCHES—HELICOIDAL AND OTHER METHODS.

22. It will often happen in public improvements and in architectural constructions that arches are so located that their parallel ends or faces cannot be placed normal to axes of the arches. Such arches are called *Oblique* or *Skew Arches*, and the acute angle the axis makes with the plan of either face of the arch is the *angle of the obliquity* of the arch.

23. The stability of an arch where the coarse stones or *voussoirs* are constructed in the ordinary manner, with their coursing joints parallel with the axis, is weakened the moment the plane of the arch faces ceases to be normal to the axis. This weakness increases as the angle of obliquity decreases.

24. Thus let Fig. 11 be the plan and elevation of a semi-circular oblique arch, whose coursing joints are parallel to its axis X X. Through H and K draw the perpendiculars H 1 and K 2. The thrust of the arch due to its weight and load would naturally be carried to the abutments in lines parallel to H 1 and K 2. But the triangles H J 1 and L H 2 are each supported by a single abutment. They therefore depend upon the bend and strength of the voussoirs within them and in the body of the arch immediately beyond them, to direct a part of their thrust and stress to the opposite

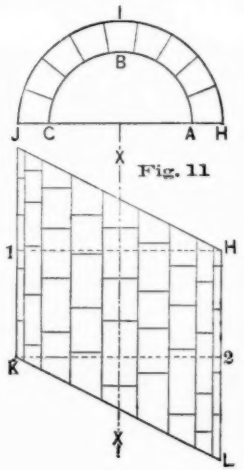

Fig. 11

abutments. Moreover, the thrust and stress thus conveyed must necessarily be in lines or planes other than those parallel to H 1 and K 2, which would cause

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an outward movement in these triangles, which would be greatest at or near the point J and L. When the angle of obliquity H J 1 or K L 2 is very acute, neither the bond or the strength of the voussoirs will resist the tendency to rupture, nor would the friction of the bedding surfaces produced by the weight and load of the voussoirs prevent the outward movement at J or L, and the arch will fail from sheer weakness.

25. It is true that small oblique arches, with their coursing joints parallel to their axles, are often with safety built. Their stability is due to the fact that as ordinarily constructed the depth of their voussoirs is in excess of what economy would in larger arches dictate. If, however, economy or other consideration should require their depth of ring to be minimum, or if the parts H J 1 and L K 2 were loaded anything like the body of the arch is capable of sustaining, the smaller like the larger arches would give away.

26. It is evident that to maintain the stability of an oblique arch it is desirable that its stress and thrust should be conveyed to the abutments in planes parallel to the oblique faces of the arch, or as near so as is possible, and also that this object cannot be attained when the coursing joints are parallel to the axis of the arch. The coursing beds to fully realize this condition should be normal to the oblique faces of the arch wherever they come in contact with them.

27. There are three methods in vogue that closely approximate this requirement. They are known as the *Logarithmic*, the *Corne de Vache*, or *Cow's Horn*, and as the *Helicoidal Methods*.

Without entering into the comparative merits of these three methods, it will be sufficient for the present purposes to state that the main advantages of the Helicoidal Method are:

The successive coursing beds and joints are parallel to one another throughout their entire lengths, rendering all voussoirs of the same warp in their coursing beds, their soffit and in their extrados; also in their bedding surfaces, except in the arch face. Therefore, all voussoirs of the same length are exactly alike, rendering only one set of templets necessary in their execution—a condition not realized in the other two methods, for both of them each stone is always different from the next one to it in the course. This consideration materially reduces the number and expense of measurements, drawings and templets. For, in the two other methods each stone has its separate and distinct templets, measurements and drawings, and are the objects of much care and anxiety. Thus it is a helicoidal voussoir will fit into any portion of its course, not requiring to be set at a particular place in its course as is required by the other methods. Again, the ring stones at equal distances from the key or center of the arch face, being of the same dimensions this method preserves the pleasing architectural effect of an arch, without the distressing effect produced by the courses increasing or decreasing in size from one side of the arch to the other as is done by the other methods.

28. Whatever may be said as to the stability of oblique arches by the other methods, it is true helicoidal arches with very acute angles of obliquity may with safety be constructed. This acuteness can be considerably less than 30°. John Watson Buck, M. Inst. C.E., places its minimum value at 25°. But it is probable that if the skew backs are maintained in their place that this value is even less.

29. Professor Hyde, in his treatise heretofore referred to, page 101, states that an advantage of this method is that owing to the fact that the coursing joints are parallel, that the courses or whole arch, with the exception of the ring stones, may be constructed of bricks, which is very true. Great caution, however, should be exercised in such construction. The crushing strength of ordinary bricks to that of ordinary building stone is as 1 to 7, and arches never should be built of bricks, unless they are of a first-class, hard burnt quality. This is especially true in public works exposed to the action of the elements. It would be better and safer to recommend that the arches between the ring stones be made of thin coursed rubble of parallel beds, which material is equally adapted to helicoidal construction.

30. Undoubtedly many oblique arches have been thus constructed of brick, either from a want of knowledge of the principles of oblique arch construction, or from erroneous ideas of the excessive cost of warped stone voussoirs over that

of straight voussoirs for the same arch. This excessive cost is but a small per cent. over right arch construction, as will be proved further on. In oblique arch construction brick work is undoubtedly cheaper than dressed stone work, but is not much cheaper than coursed rubble work, while the latter is far more stable, but neither will compare with dressed stone for strength.

HELICOIDAL METHOD.

31. The helicoidal method of construction of oblique arches is one in which the coursing beds of the voussoirs are

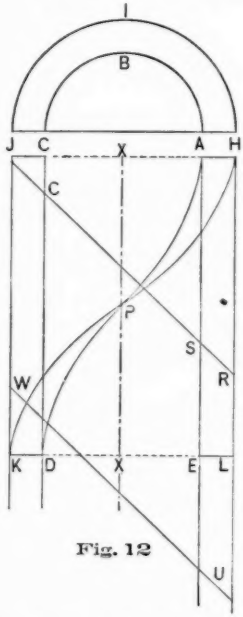


Fig. 12

radial helicoids, whose intradosal and extradosal helices are parallel curves.

32. A helicoid, as stated in article 8, is generated by a right line perpendicular to, and moving on, the axis of the arch as one directrix, and on a helix as the other directrix, and the arch helicoid is that part of this surface generated by that portion of the generating line that is equal to the depth of the arch, and is included between the intrados and the extrados.

33. J W U H in Fig. 12 is the plan of an oblique arch A B C, and H R J equal to K W U is the angle of obliquity, and the helicoid H P K—A P D represents a coursing bed of one course of voussoirs.

34. In the plan of Fig. 13 the extrados is removed in order to show the intradosal helices of the successive courses and the traces 1 2, 3 4, &c., of the helicoids or coursing beds upon the *imposts* A H and C J of the abutments, while in Fig. 14 the traces 1 2, 3 4, &c., and the corresponding extradosal helices, are shown. Were it not for the confusion of

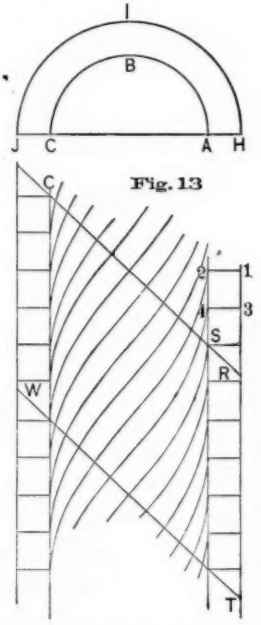


Fig. 13

curved lines, both the intradosal and extradosal helices and the traces 1 2, 3 4, &c., might be given in the same plan, and each helicoid or coursing bed would be shown as in Fig. 12. It should be noticed that the traces 1 2, 3 4, &c., in the face of the impost are elements of the arch helicoids, and are, therefore, normal to the spring lines of the arch, and this is true whether the arch is a full semi-circle or only a segment.

CHAPTER IV.

THE FOREGOING PRINCIPLE APPLIED TO HELICOIDAL OBLIQUE ARCHES AND DEDUCTION OF FORMULÆ.

35. In the application of the foregoing principles to helicoidal oblique arches a

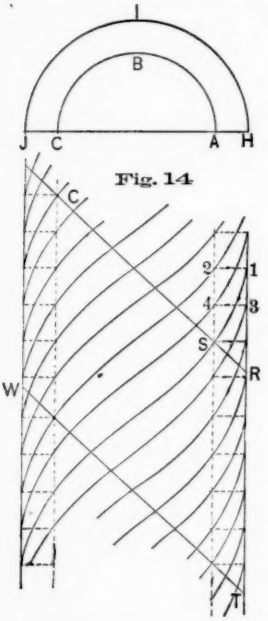


Fig. 14.

constant relation is established for any given case between the right diameter of the arch and the length of either the intradosal or extradosal helix of the arch helicoid. In the development of the intrados the helix is drawn perpendicular to a straight line, joining impost extremities of the arch face end of the developed intrados, and, as there is a constant relation between the length of the intradosal and extradosal helices, the construction would also establish a constant relation of the diameter of the arch to the length of the extradosal helix.

Again, it should be observed that since the skew face of the arch in plan is a straight line, the development of either the intradosal or extradosal arch face ellipse will be a curved line, and that the straight line in the development joining the impost extremities of the ellipse will divide this curve line into equal curves.

36. Thus, let A B C — H I J (Fig. 16) be right section or elevation of an oblique arch, and S C V U the plan of its intrados. Draw A G equal to the semi-circumference A B C perpendicular to A E and divide A G and A B C into the same convenient number of parts of equal length and draw the straight line G S. It is evident that the middle point of the ellipse S C in the plan will, in the development, be the middle point of G S. Then, through the points of division in A B C and A G draw lines parallel with A E, and through the points of intersection S C draw lines parallel with A G, the points of intersection of these lines the parallel with A G, with the corresponding lines parallel with A E, drawn through the points of division in A G, will be points in the curved line S X′ G.

Through S draw S F perpendicular to the straight line S G. S F will be the development of the helix S D, whose cylindrical length is S E, and from S F and S E the curve S D may be obtained according to article G. The angle F S E equal to S G A by construction, is the *angle of the intrados* and is designated by β.

37. In Fig. 16 the intrados and extrados of the arch are shown in plan, elevation and in development. The extradosal helix R K is determined from the intradosal helix S D by drawing through S and F, S R and F M perpendicular to R L and to M N and joining R and M by R M. Then R M will be the development of the helix R P K, whose cylindrical length R L equals S E of the intradosal helix S P D. From R L and R M the curve R P K in the plan can be obtained in the same manner that S P D was. Also the curved end R X′ N is projected in the development similarly for H N and H I J as S X′ G was from A G and A B C. The angle M R L is the *angle of the extrados* and isdesignated by β'.

38. Let r be the right radius of the intrados; r' the radius of the extrados, b the depth of the arch, and θ the complement of the angle of obliquity. Then πr = A B C = A G, and $\pi r'$ = H I J = H N. Then the relation of the diameter or radius to the helices will be obtained from the following formulæ:

$$A S = 2r \text{ tang. } \theta = \pi r \text{ tang. } \beta \qquad (8)$$

$$\therefore \text{ tang. } \beta = \frac{2 \text{ tang. } \theta}{\pi} \qquad (9)$$

This eq. is true and β bears this relation to θ so long as S F is normal to the straight line S G. Sometimes it will be necessary to alter this relation of S F and S G, so that S F will pass through a given point in U Q. This alteration is always

slight, and eq. (9) can readily be corrected for it.

$$\text{C S cos. } \theta = 2r, \text{ or C S} = \frac{2r}{\text{cos. } \theta} \quad (10)$$

$$\text{G S cos. } \beta = \pi r, \text{ or G S} = \frac{\pi r}{\text{cos. } \beta} \quad (11)$$

Again $(\text{E F} = \pi r) = \text{S E tang. } \beta$,

$$\text{or S E} = \frac{\pi r}{\text{tang. } \beta} = \frac{\pi r'}{\text{tang. } \beta'} = \frac{\pi^2 r}{2 \text{ tang. } \theta} \quad (12)$$

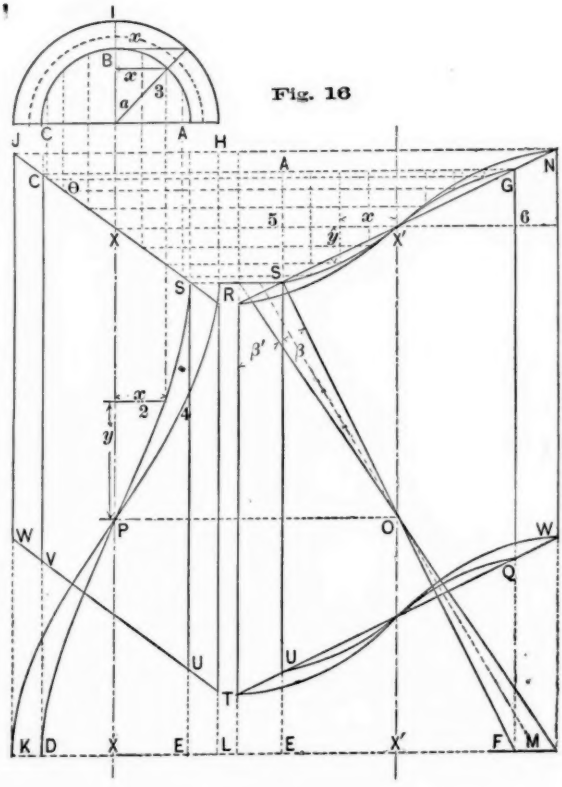


Fig. 16

$$\text{S F sin. } \beta = (\text{E F} = \pi r) \text{ or S F} = \frac{\pi r}{\text{sin. } \beta} \quad (13)$$

$$\text{R M sin. } \beta' = (\text{L M} = \pi r') \text{ or R M} = \frac{\pi r'}{\text{sin. } \beta'} \quad (14)$$

39. In Fig. 16, let X X be the axis of y and P O that of x, with the origin at P, and the equation of the curve S P D with reference to these axes, will be obtained in the following manner:

Let 2 be any point in S P D, whose ordinates are x and y, the angle 3 X B be a, and n be the quotient of the length of the arc B 3, divided by the length of the semi-circumference A B C, then

$$a = n\,180°, \quad x = r \text{ sin. } a, \quad \text{and } y = n\,\text{S E}$$

$$= n \frac{\pi^2 r}{2 \text{ tang. } \theta} \quad \therefore r = \frac{x}{\text{sin. } a} = \frac{2y \text{ tan. } \theta}{n\pi^2 r} \quad (15)$$

(15) is the equation of the curve S P D, so that if either x or y is given, n and y or x can be obtained. It is also the equation of the plan of the normal helix to S P D at P, when y equals the nth part of the normal helix's cylindrical length, or n K I in Fig. 2.

40. To determine the equation of R P K let x and y be the ordinates to any point

4 in it, referred to same axes as in article 39. Then, as before,

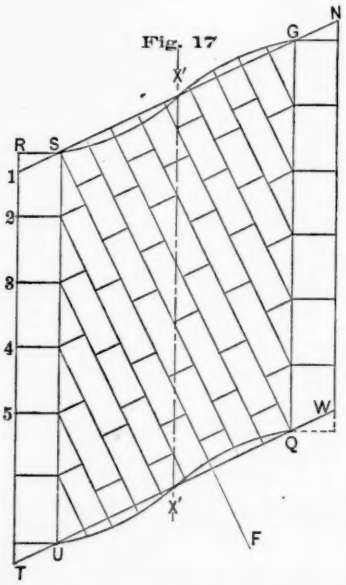
$$y = n\frac{\pi^2 r}{2 \text{ tang.}\theta}$$

but $$x = r' \text{ sin. } a = (r+b) \text{ sin. } a$$

$$\therefore r = \frac{2y \text{ tang. } \theta}{n\pi^2} = \frac{x}{\text{sin.}a} - b \quad (16)$$

41. To determine the equation of the end curve S X′ G of the development with reference axis 5 X′ 6 of x, draw n

Fig. 17



through X′ parallel to A G and axis of y X′ X′, let x and y be the ordinates of any point y in S X′ G. Then by reference to Fig. 16 it will appear

$$x = n\,\pi\,r \text{ or } r = \frac{x}{n\,\pi}$$

$$y = r \text{ sin. } a \text{ tang. } \theta \text{ or } r = \frac{y}{\text{sin. } a \text{ tang. } \theta}$$

$$\therefore \frac{x}{n\,\pi} = \frac{y}{\text{sin. } a \text{ tang.}\theta} \quad (17)$$

42. And for the corresponding extradosal end curve R X′ N we have as in 41

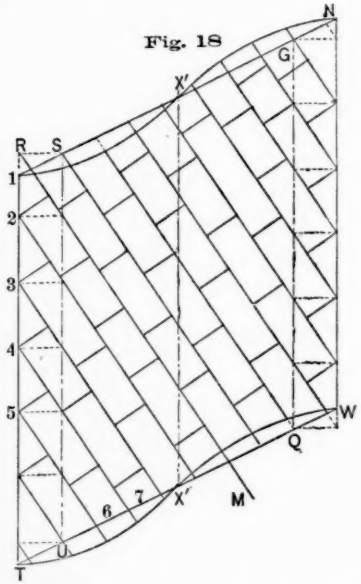
$$x = n\,\pi\,r' \text{ or } r' = \frac{x}{n\,\pi}$$

$$y = r' \text{ sin } a \text{ tang. } \theta \text{ or } r' = \frac{y}{\text{sin. } a \text{ tang. } \theta}$$

$$\therefore \frac{x}{n\,\pi} = \frac{y}{\text{sin. } a \text{ tang. } \theta} \quad (18)$$

43. It should be noted that for a given angle a the points 2 and 4 and 7 and 8 are in lines perpendicular to the axis of the arch. Also that in practice it will be impossible to make full-sized drawings of of the curves S P D, R P K, S X′ G and R X′ N for their entire lengths. The four equations above will be useful in exactly determining any portion of either one of them, and be of great assistance in laying out the work for construction.

Fig. 18



44. In a properly constructed arch the resultant of all faces acting upon it should be confined within the middle third of the depth I B of the arch.

When S F in the development is perpendicular S G R M cannot be perpendicular to the line joining the impost extremities of arch face ends of the developed intrados. If then for any reason it is desirable to alter the direction of S F it should be so altered whenever practicable. The dotted line midway between S F and R M (Fig. 16) should approach to or become normal to the straight line, join the extremities of the development of the middle line of the face of the arch shown by dotted line in the elevation midway between A B C and H I J.

45. In intradosal development the coursing joints are laid out in the following manner. Let S U Q G (Fig. 17) be the intradosal development of an arch, and let R T and N W be the outer edges of the extradosal development. Through S draw S F perpendicular to the straight line S G. Divide the straight lines S G and U Q each into an odd number of parts of equal length in order to show a key in the arch face. If S F should not pass through one of the points of division in U Q the length of the arch should be increased or decreased, or altered the direction of S F as indicated in the last article, so that it will pass exactly through one of the points of division in U Q. Then draw lines through the points of division in S G and U Q parallel to S F. The portions of these parallel lines between the ends R G and U Q will be the intradosal coursing joints of the successive courses in the development. The soffit face between them may then be divided into convenient lengths, as shown by drawing their heading joints at right angles to them.

46. Let 1 T W N, Fig. 18, be the corresponding extradosal development to Fig. 17, showing the springing edges S U and G Q of the extrados. Through S draw S R perpendicular to S U, and lay off the spaces R 2, 2 3, 3 4, &c., Fig. 17, on R T. Then through R draw R M parallel to R M, Fig. 16, or as altered by Fig. 17, and through 2 3 4, &c., and the corresponding points in N W, draw lines parallel to R M. Then divide the remaining spaces of straight lines 1 N and and T W into equal parts equal to the distance 6 7 on T W, and through the points of division draw lines parallel to R M. These parallel lines will be the extradosal coursing joints in the development.

VENTILATION.

From "Nature."

In modern life, with its enormous populations living under artificial conditions in towns and cities, the subject of ventilation, or the supply of sufficient pure air to each individual for the maintenance of health, has assumed, as it has become more generally understood, a vast and national importance. Its importance has been clearly demonstrated in many instances by a greatly diminished death-rate in places where overcrowding on space or in houses, formerly existent, has been remedied, and especially by a decrease in those diseases which are now generally recognized as preventible. Thus, since attention has been paid to the amount of cubic space and the supply of fresh air per head in barracks, the death-rate from phthisis or destructive diseases of the lungs in the army has fallen from 10 to 2 per 1,000; and typhus, formerly very prevalent in the gaols of the country and in the crowded courts of our large cities, is now almost unknown in these situations. That there is still a vast amount of disease and death which could be prevented by a more general recognition of the absolute importance of a pure supply of fresh air under all conditions, is a fact whose truth we recognize when we observe the numbers of scrofulous and ricketty children and consumptive adults in our large centers of population. Many houses in the poorer parts of towns are absolutely debarred from obtaining fresh air and light by their surroundings. Built almost back to back, or fronting into narrow courts or passages closed at one or both ends, the sunlight never penetrates for months in the year, and a free current of air is an impossibility. Fortunately the Legislature has recognized this evil, and the Acts known as Sir Richard Cross's and Torren's are intended to remedy such a state of things, and, where enforced, have succeeded in removing buildings which no structural alterations could improve. The erection of huge blocks of Industrial Dwellings, whilst affording vastly superior accommodation to the working classes, has not always secured efficient ventilation in these respects for certain of the tenements. We have seen instances of lofty blocks being built in such a way as to

enclose a narrow and well-like court, in which the atmosphere is always stagnant, and from which the inner rooms derive all their light and air. Cottage buildings, with sufficient space in front and rear, are far preferable to lofty blocks placed in rows; but as they do not house the same number of people for the space occupied in crowded districts, where land is of such enormous value, the rents must necessarily be higher, the other accommodation being the same. The air of enclosed courts is often damp, and being stagnant allows suspended particles to fall and foul gases to accumulate in it, thus forming a suitable "nidus" for the growth and cultivation of such disease germs as are capable of existing in the air. It is true that the death-rates appearing in the reports of many of the Industrial Dwellings Companies' are exceptionally low, but we must remember that a very large proportion of the working classes die in hospitals and not in their own houses, and such sources of error require to be very carefully eliminated. Of late years artizans' dwellings have been built on better principles, the experience derived from the sanitary failures of certain of the earlier erections having been taken to heart.

In the model by-laws of the Local Government Board it is provided that no new street is to be less than 36 ft. in width, that the frontage of any new building not standing in a street shall be at least 24 ft. in width, and that there shall be an open space at the rear of any new building and belonging to it of an aggregate extent of 150 square ft., this space not to be in any case less than 10 ft. wide, and if the height of the building exceed 35 ft., to be not less than 25 ft. wide. If these rules could be always enforced in the cases of new buildings, an improvement would be gradually effected in and around towns in the poorer districts which is greatly needed.

From what has been said it will be seen that one of the principal points in any system of ventilation is that the air to be admitted into a building should be pure, and this can be ensured if there is no impediment to the free circulation of currents of air on the outside. We come now to the second part of the subject, viz., the vitiation of air that is constantly going on in inhabited places from the respiration of men and animals, and from the combustion of gas, lamps, and candles, and the methods by which this vitiated air may be replaced by pure external air. The composition of the atmosphere is as follows in 1,000 parts: nitrogen, 790.0; oxygen, 209.6; carbonic acid gas, .4, and traces of ozone, ammonia with nitrous and sulphurous acids in the air of towns, and a variable amount of aqueous vapor. The air taken into the lungs of a human being has this composition, but that expired differs from it in the following particulars, the nitrogen remaining the same: the oxygen which is the vital principle of air is diminished 4 per cent., the carbonic acid is increased 4 per cent., the expired air is saturated with aqueous vapor and is heated nearly to the temperature of the body, 98° Fahrenheit, and contains a small proportion of foul, decomposing organic matter, which exists partly in the form of vapor and partly as solid suspended matter (epithelial dust and scales). This organic matter. though small in amount, is the most injurious quality of expired air, giving to the atmosphere of an ill-ventilated room its close and disagreeable smell. Those who are familiar with the interiors of courts of law, with the pits and galleries of theaters, or with crowded buildings generally, are also familiar with the headaches, the lassitude, and the "malaise" produced by breathing for some hours a vitiated atmosphere. In analyses of such air nearly ten times more carbonic acid has been found than is normally present in the outer air, and when this excess is known to mean a deficiency in oxygen and a corresponding excess in organic vaporous exhalations and suspended matter from the breath and bodies of the persons present, the foul nature of the atmosphere can be realized. The slow deterioration in health, which results from the constant breathing of foul air, is one of its most important results, and causes a predisposition to, and lessened power of, resistance to attacks of disease.

An adult man of average size takes in and breathes out, when at rest, about 30 cubic inches of air at each respiration, this act being performed about seventeen times in a minute, so that in one hour about 17 cubic feet of fresh air will have been vitiated to the extent of containing

4 per cent. of carbonic acid—that is to say, about .7 cubic foot. Such a man gives out when at rest, therefore, nearly .7 cubic foot carbonic acid gas per hour. Now it has been found by Dr. De Chaumont, by chemical examination of a large number of samples of the air of inhabited rooms, that the amount of carbonic acid in the outer air being .4 per 1,000, no close smell is perceived in the air of a room until the carbonic acid reaches .6 per 1,000, or exceeds by .2 per 1,000 that in the outer air, the close smell being always due to the foul organic matter in the impure air, which increases *pari passu* with, and is therefore estimated by the amount of carbonic acid present. It has been assumed by De Chaumont, and experience has fully confirmed this assumption, that we can breathe with immunity air vitiated to this slight extent, but that we should not allow any greater vitiation. We may take it, therefore, that the object of ventilation is to supply sufficient pure air to a room to prevent the carbonic acid rising above .6 per 1,000, this quantity being known as the limit of respiratory impurity. It may be asked why should not the air of our rooms be as pure as the air outside? No doubt this would be desirable, were it not that it involves a continual renewal of the inner air by the outer, which means in cold weather an unceasing draught at an unbearable temperature. We have seen that an ordinary adult man expires .7 cubic foot of carbonic acid in in one hour when at rest, now if such an individual were enclosed in an air-tight chamber, 10 feet high, 10 feet wide, and 10 feet long—that is to say, in a chamber containing 1,000 cubic feet space—in one hour the carbonic acid in this chamber would have had added to it .7 cubic foot of carbonic acid: the air originally contained .4 parts of carbonic acid in 1,000 parts, so that after one hour it would contain $.4 + .7 = 1.1$ parts of carbonic acid per 1,000 or $1.1 - .6 = .5$ parts per 1,000 above the permissible limit for health. But if the subject of our experiment were enclosed in a room containing 3,500 cubic feet of space, in one hour the amount of carbonic acid would be only $\frac{3.5 \times .4 + .7}{3.5} = .6$ per 1.000, *i. e.*, the limit would have just been reached, and at the end of a second hour, to keep the carbonic acid to this limit, another 3,500 cubic feet of fresh air must have been allowed to enter the room. That is to say, an adult man requires when at rest 3,500 cubic feet of fresh air per hour; a woman or child requires proportionally less. For any individual above twelve years of age, we may take as an average the amount of carbonic acid expired per hour as .6 cubic foot, and for such an average individual 3,000 cubic feet of fresh air per hour is necessary. We can now appreciate the importance of cubic space, for if we are to supply 3,000 cubic feet of fresh air to every individual above twelve years, in a room, and the amount of space, suppose, in a dormitory where ten persons sleep is only 300 cubic feet per head, then 30,000 cubic feet of fresh air must be supplied per hour—that is to say, the air of the dormitory must be completely changed ten times in this period, a proceeding which would cause in any but the very warmest weather a very disagreeable draught. But if the cubic space per head be 1,000 feet, then the air of the dormitory need be changed only three times per hour, and if such renewal be effected steadily and gradually no draught need be felt. We may mention here that a certain amount of superficial or floor space is necessary for each individual, for if the height of the room is much over 12 feet, excess in this direction does not compensate for deficiency in the other dimensions, although the cubic space may be the same; thus it would not be the same thing to allow a man 50 square feet of floor space in a room 20 feet high, as to allow him 100 square feet of floor space in a room 10 feet high, although the amount of space allotted to him in each case would be the same. It may be interesting here to mention that in common lodging-houses under police regulations, 240 cubic feet of space are allotted to each adult, in barracks about 600 cubic feet, in general hospitals about 1,000 cubic feet as a rule, and in infectious fever hospitals from 1500 to 3,500 cubic feet—in these latter institutions the floor space allowed per bed is from 150 to 300 square feet. From the report of the royal commission on the housing of the working classes it would appear that even the low allowance of the common lodging-houses is very often not attained in the crowded room.

of tenement honses, and an enormous number of cellars are still inhabited in our large towns, although they presumably come up to the requirements of the Publich Health Acts as regards their ventilation.

Gas, candles, and lamps use up oxygen and produce carbonic acid and water. A cubic foot of coal gas produces, when burnt, 2 cubic feet of carbonic acid, and since a common burner consumes 3 cubic feet of gas in an hour, it produces 6 cubic feet of carbonic acid in the same period. Therefore, as much air should be supplied to dilute the products of its combustion as would be necessary for three or four men. It is far better, however to use such gas lamps as are shut off from the air of the room. These receive the air necessary for combustion from without, and the products of combustion are carried off by a special channel to the outer air. The electric light uses none of the oxygen of the air and gives off no carbonic acid nor water, rnd is for these reasons far preferable to naked flames for lighting purposes.

Ventilation is said to be carried on by natural or by artificial means. In the former are included (1) diffusion of gases; (2) action of the wind by perflation and aspiration; (3) movements caused by differences in weight of masses of air at different temperatures. By the latter, although the same principles are involved, is meant exhaustion of air by heat or by steam from apartments or propulsion of air into such spaces by mechanical means, as fans. Diffusion causes a rapid mixing of different gases placed in contiguity; thus the gaseous impurities of respired air mix with the fresh air in a room until homogeneity is established. Diffusion, however, does not affect the suspended matters which tend to fall in a still atmosphere. Consequently organic matters which exist principally as minute solids in a state of suspension in the air, are not affected or removed by diffusion. The wind when in motion causes a partial vaccum in the interior of tubes, such as chimneys and ventilating shafts placed at right angles to its course. The air in these tubes being thus partially aspirated or sucked out by the action of the wind, to restore the temporary vacuum so made, air from below rushes up to take its place, a continual current in a perpendicular direction being thus set up. Perflation by winds is the setting in motion of masses of air by the impact of other masses. This action is illustrated when the windows on opposite sides of the room are fully open. The room is rapidly and continually flushed with air, an enormous effect being produced, for it has been estimated that the air of such a room may be renewed many hundred times an hour, even when the movement of air outside is only two miles an hour or $1\frac{1}{2}$ feet per second, equivalent to a very gentle and almost imperceptible breeze. Such a method is of unquestionable utility for rapidly changing the air of an unoccupied room, and may be generally put in operation in summer in inhabited rooms when the temperatures outside and inside the house approximate. In any system of ventilation that depends entirely on the wind there is always the difficulty of regulating the velocity of the current according to the amount of movement of the air, and during complete calms the action is nil. For ventilating the hold and interiors of ships at sea, the wind may be most advantageously utilized. A cowl placed so as to face the wind conducts the air below, whilst another reversed so as to back to the wind allows the used air to escape.

The movement due to masses of air at different temperatures is the natural force chiefly relied on for ventilating the interior of houses. The air of inhabited rooms in this climate, except in warm summer weather, is at a higher temperature than the outer air; hot air is lighter than cold air, and will rise for cold air to take its place—in fact, heated air is displaced upwards by colder and denser air. In a room as usually constructed with sash windows, with a fire-place and chimney, but without any special means of ventilation, when a fire is burning in the grate the heated air of the room in part ascends the chimney-flue, and in part rises to the ceiling. Cold air from outside will then enter, if the windows be closed, under the door, under the skirting boards, between the sashes of the window, and through any other chinks or apertures due to loose fittings. The bricks and plaster of the walls are also porous to a slight extent, and if not covered with paint or wall paper will admit air to a limited extent. Thus a large volume of

air may be entering a room in cold weather when the fire is burning although there be no visible inlets, and the amount of air thus supplied may be sufficient for the needs of two or three persons if it were properly distributed. But such is not the case. The cold air, which enters chiefly near the floor, takes as straight a course as possible to the fire-place, producing a disagreeable draught to the feet of the occupants, whilst the heated and vitiated air near the ceiling is left undisturbed. It has been found practically that to prevent draughts, and to insure a thorough distribution, fresh air should be admitted into a room above the heads of the occupants, an upward direction being given to it, so that it may impinge on the ceiling, mix with, and be warmed by, the heated air in this situation, fall gently into all parts of the room, and be gradually removed by means of the chimney-flue or any other outlet. The inlet openings for fresh air now most in use are intended to serve this purpose. For sash windows Hinckes Bird's method, now so well known, of placing a solid block of wood under the lower sash of the window so as to raise the top of the lower sash above the bottom of the upper, admits the air in an upward direction to the ceiling above the heads of the occupants. Holes bored in a perpendicular direction in the bottom of the upper sash, louvered panes to replace one of the squares of glass, an arrangement for allowing one of the square of glass to fall inward upon its lower border and providing it with side cheeks, or a double pane of glass in one square open at the bottom outside and at the top inside—all effect the same purpose and are simple and inexpensive contrivances. Wall inlet ventilators, as the Sherringham valve and Tobin's tubes, are constructed on the same principles, fresh air, which in towns may be filtered through muslin or cotton wool, or made to impinge upon a tray containing water so as to deposit its sooty particles, being admitted at a height of about 6 feet from the floor and directed upwards towards the ceiling. The usual outlet for vitiated air is the chimney-flue, and this for an ordinary medium-sized sitting-room, with a fire burning, is sufficient for three or four people, provided no gas is alight, or the gas lamp has its own special ventilating arrangements. With an ordinary fire, from 10,000 to 15,000 cubic feet of air are drawn up the chimney in an hour. Valves placed so as to open into the flue near the ceiling are sometimes used as outlets for foul air, such are Neil Arnott's and Boyle's valves, which permit air to pass into the flue, but prevent its return; the only objections to their use are that they occasionally permit the reflux of smoke into the room, and their movements backwards and forwards cause a slight clicking noise. In all new buildings where efficient ventilation is desired, it would be preferable to construct a shaft at one side of, or surrounding the chimney-flue, with an inlet near the ceiling of the room and the outlet at the level of the chimney top, so that the air escaping from the room would have its temperature kept up by contact with the chimney, thus aiding the updraught, whilst the risk of reflux of smoke would be avoided. In all new domestic buildings a very great improvement might be effected by providing for the warming of the air before its entry into the apartments. The window and wall inlet ventilators just described are occasionally productive of draughts in cold weather, so that it is more usual to find them closed or stopped up than in action, or else admitting a very insufficient supply of air; but if the air be warmed before admittance to an agreeable temperature a very large amount may be allowed to enter without the fact being known to the occupants. The ventilating stove invented by Captain Galton, the Manchester school grate, and other forms effect this purpose in the following manner: Behind the grate, which is lined with fire-clay, is a chamber into which fresh air is admitted by a pipe from the outside. The air, here warmed, is admitted into the room by a pipe opening at about the level of the chimney breast and guarded by a grating which can be opened or closed as found convenient. In the Manchester school grate the warmed air is admitted by vertical pipes, like Tobin's tubes, opening on a level with the chimney-piece. The danger in these grates is that cracks may be formed by the heat of the fire in the joints or in the cast-iron plates which surround the air chamber, and thus direct communication be established between the grate and air chamber with the result of deleterious products of combustion being admitted into the air of the room.

When the stove is lined with fire-clay there is no danger of the air in the chamber being overheated, producing charring of the organic matter in the air and an offensive smell, which is often noticed around stoves where this precaution has not been taken. In Mr. Saxon Snell's ventilating thermhydric stove the fresh air is warmed by passing over hot water pipes in the stove before entrance into the room, the hot water being derived from a small boiler at the back of the grate. The temperature of the water is not high enough to overheat the air.

Gas is being gradually introduced for heating purposes, and with a reduction in its price we may look forward to its its more extended use. There are several ventilating gas stoves by which air is admitted into a room warmed after passing through the stove. It is important to regulate the heat carefully so as not to overheat the stove and the air which is passing through. In churches and other public buildings air is usually warmed before entry by passing over hot water pipes which circulate around the building under the floor. In all large buildings the combustion of gas may be made a very effective means of getting rid of foul air. It has been found by experiment that the combustion of one cubic foot of coal gas causes the discharge of 1,000 cubic feet of air. In theaters where gas, although being gradually replaced by the electric light, is still much used, the extraction of foul air from the roof of the building by the sunlight burners presents no difficulty. The difficulty experienced is the introduction of fresh air from below without causing draughts. In private houses the use of an extraction shaft over the gas chandelier, or a Benham's ventilating globe light, or a Mackinnel's ventilator, greatly aids the extraction of foul air from the ceiling, and is then directed horizontally by flanges so as to be distributed over the room. Outlets in the ceiling of a room may become inlets when a strong fire is burning, as the draught up the chimney will overbalance the extractive power of the gas and cause all other openings into the room to be inlets. We may here mention an ingenious method for warming the air admitted by Tobin's tubes into a room: a row of small Bunsen burners encircles the tube at its foot, and the products of combustion are conveyed away by a tube which surrounds the Tobin and opens into the outer air.

In large public buildings, where expense is no object, a combined method of ventilation by propulsion and extraction presents many advantages. The amount of air admitted can be easily regulated, warmed, cooled, or moistened, and freed from impurities by filtration, and enormous volumes are capable of being so supplied by propulsion and removed by the extractive powers of a furnace. In the Houses of Parliament where this system is in operation, air is propelled by rotatory fans along conduits to the basement, where it is warmed in winter by passing over steam pipes, and then passes upwards through shafts into the space beneath the grated floor of the House. The heat can be regulated by covering the steam pipes with woolen cloths, and in summer the entering air can be sprayed with water or cooled by passing over ice in the conduits. The vitiated air in the House passes through a perforated glass ceiling in the roof, and is then conducted by a shaft to the basement of the Clock Tower, where it passes into the flue of a large furnace.

The introduction of electricity for lighting and of gas for heating purposes will, in the case of both public and private buildings, considerably modify the methods of ventilation now most generally used.

According to Messrs. Moss & Co.'s "Steamship Circular," "the anticipation that a very considerable reduction of tonnage would be shown when the returns of the output for 1885 were made up, has proved correct. Statistics are briefly thus: Tonnage built in United Kingdom, 1883, 1,250,000 tons; 1884, 958,000 tons; and 1885, 540,000 tons; or a reduction of 750,000 tons on the output of two years since. This should have a serious effect on the value of steam shipping, and if, as seems very probable, the output of 1886 will be even lower than 1885, we may then reasonably hope that the excessive over-production has been fairly checked, and that supply and demand will be more evenly balanced."

ELECTRICAL TRANSMISSION OF POWER.

By CHAS. J. VAN DEPOELE.

From "The Telegraphic Journal and Electrical Review."

During the summer months of 1885 I entered into a contract with the directors of the Toronto, Ont., annual exhibition, to run a train of three cars and a motor car from the street railway terminus to the upper grounds of the exposition, a distance of a mile. Having only a single track, I had to prepare here for a light train and good speed. The plant consisted of the following:

One steam engine, 10 by 16, running 125 revolutions per minute, driving an ordinary 40-light (arc) machine, having an E M.F. of about 1,400 volts and an intensity of current of about 18 ampères. The engine and dynamo were placed in Machinery Hall, close to the boiler room.

The dynamo was connected, one pole with the rails, which were fastened together by means of fish plates, and the other pole to an overhead wire, hanging over the center of the track, by means of arms extending from poles placed along the length of the track. On the top of the car, on which the motor was placed, was a contact wheel carried by a pivoted beam, the latter being provided with a spring on one end pressing the wheel at the other end up against the underside of the overhead wire. This contact wheel was in communication, by means of a flexible cable, with the switches, rheostat and motor; from the motor the current was carried to the axles of the wheels, the wheels to the track, thus closing the circuit upon the generator.

We began placing poles, &c., on September 1st, and made our first trip on September 5th. From beginning till end not the slightest hitch occurred, running regularly from 8 A.M. till 10.30 P.M. without stopping a minute. On many occasions we carried from 225 to 250 people. One end of the track we had a 200 feet curve to start, then a level of some 2,000 feet, with two curves of about 1,000 feet radius, then a grade of some 1,500 feet, gaining gradually to about 6 per cent. The rest of the road had a downward grade to the terminus, which made it a disadvantage in starting. As above said, the distance was a mile, and the round trip never exceeded eight minutes, so that, including starting and stopping, we made for part of the way at least 30 miles per hour. During the last five days of the fair we carried 50,000 people. The consumption of coal, as given by Doty & Sons, who ran the engine, was on an average of 1,000 lbs. in 10 hours.

The next step was to South Bend, Ind., where we eqipped four ordinary street cars, one large open car with a 10 H. P. motor, and the other three closed cars each with a 5 H. P. motor. The large car was run for the first time on November 14th, 1885, and was packed with humanity to its utmost capacity. Everything worked like a charm. The plant consists at present of the following:—A 50 H. P. water wheel, and two 20 H. P. generators, and, as above stated, one 10, and three 5 H. P. motors. The track is laid with the ordinary flat rail, so in order to connect the rails together we placed copper plates 3 inches by 12 inches under the joints and spiked the rails down on both sides of the track, so that there is no chance of breaking circuit. As will be understood, the rails in the present case form again one part of the circuit, the other part consists of a copper wire $\frac{1}{4}$-inch diameter suspended above the track, from cross wires fastened to poles placed near the curbstone, and at a distance of about 100 feet apart. From the under side of this copper wire or conductor hangs a carriage, fastened to a flexible cable, passing to the inside of the car, where it is in connection with the switches, the motor, &c.; this carriage travels along with the car, and makes a perfect contact. After the first trial of November 14th the 5 H. P. motors were soon in place and have worked admirably. The tracks are never perfectly clean, on account of constant traffic over the road, but since both rails are connected and also all four of the wheels, it is almost impossible to break circuit between the motor and the rails. The

cars have run right along through mud and snow, and no trouble has been experienced with the circuit.

On running the four cars at once, the generators work perfectly, from 6 in the morning until 11 P. M., requiring not the slightest attention; the brushes are set in the morning, and are not touched afterwards. Every car works independently, back or forward, without interfering with the others; the division of the current leaves nothing to be desired. The only trouble we have encountered with the plant has been with some small mechanical details, such as link bolts breaking, &c. These, of course, being small matters are easily remedied. The main point here was the electrical part, and this has proved to be an unqualified success.

The length of the present road is about $2\frac{1}{2}$ miles. The other roads will be equipped as soon as the weather allows of the placing of the poles for the cross wires.

On the 6th day of October, 1885, we entered into a contract with Mr. McConnico, President of the New Orleans Exposition, to run a train of cars in the grounds, with a carrying capacity of from 180 to 200 people. This road is similar to the one in Toronto, nearly a mile long, running from St. Charles Street main entrance, along the Government buildings through the grounds, to the main building and Art Hall.

All was ready for operation for the opening day, but on account of delay in obtaining steam power, we only began running regularly on December 14.

The heaviest work we have done, so so far, is in Minneapolis, Minn., and that during the winter months when snow and ice are faithful companions on the track; whether invited or not, they are there, and never fail.

Before undertaking the job, I was very much afraid that electricity would not be practicable in a climate where the thermometer rises seldom above the freezing point for at least three months of the year. All my fears, however, have been removed in the past six weeks; we have ascended the grades and turned the curves with at least as much facility as the steam dummies.

The electrical plant consists at present of one 60 H. P. generator and a 50 H. P. motor. Our circuit consists of the rails for one side and an overhead copper wire $\frac{3}{10}$-inch in diameter for the other side.

In South Bend we have water power as the prime motor. We ran for the first time on New Year's Eve, 1885, and continued on New Year's Day. The water wheel had no governor, and we found it rather dangerous for the generator. As the water wheel had to be governed by hand, it was impossible to keep the speed anywhere near constant. It was decided to put a governor on before running regularly. Several trips, however, were made over the entire length of the road, giving entire satisfaction. The weight of motor is 3,500 lbs., and the total weight of motor car or electric locomotive is 8 tons. The passenger cars in use here are similar to those on the New York Elevated. In some instances we had three to four inches of solid ice on the track and broke our way through it without the least trouble; in a few days the water power will be in shape to run regularly, when we will run on schedule time.

Thus far we have demonstrated that electric railroads can be operated anywhere where the steam motor can go, and that there is much in favor of the electric motor in cold countries is very evident; there is no danger of pumps freezing up, nor of breaks becoming inoperative; no water tanks are needed along the road, nor is there any coal to be taken; in fact, there are thousands of advantages in the application of the electric locomotive on street and other railroads. Whenever water power is obtainable the economy need not be disputed, and even in the case where steam is to be used as a prime motor there will be considerable economy.

No cheaper or better plant can be expected to run light trains on suburban roads than the electric motor; as, for instance, in the Detroit road now in progress, connecting the latter city with Dearborn, a single train will be run with six large-sized street cars; the speed will be from 15 to 20 miles an hour, the length of this road is nearly three miles, and it will be in operation in a few weeks.

A similar road will be in operation early in the spring in Appleton, Wis. In this case, however, six cars will be

equipped with 10 horse-power motors and run independently; the length of road is about eight miles; the speed about ten miles per hour. Water power will be used to run the generators.

The street railway in Montgomery, Ala., is now being equipped with our motors, twelve cars in all, and will be running within thirty days.

In all the above places we are using overhead conductors, which are no more of an obstruction than the ordinary telegraph and electric light wires; in fact much less, since the conductors are over the center of the roads, so that wherever wires are allowed for other purposes, they cannot be refused for the present purposes. I do not believe, however, that overhead wires would be practical in large cities where other wires have to be buried; but in this case the electric conductors can be placed underground in conduits similar to those used for cable cars. This will be much more expensive than the overhead conductors, but it will be a permanent an practical fixture.

I feel sorry that I have not found more time to prepare some figures with regard to tests of motors and general transmission, but the above is a *résume* from practical experience and facts on the track instead of on paper. I am a solid believer in the saying that experience is the best teacher, and to all the above I have attended personally from beginning to end, and am more than ever convinced that the electrical transmission of power has not only ceased to be ephemeral, but has become a real fact and a blessing to the world. All is ready, it has only to be applied judiciously and success is imminent. Thousands of horse-power are now running waste in our waterfalls which can all be utilized to advantage, in some cases running our tramways, in others our factories, &c., giving at the same time light and cheer during the absence of old Sol.

A NEW SUBSTANCE FOR SUBAQUEOUS FOUNDATIONS.

By E. GAERTNER.

Translated for Abstracts of Institution of Civil Engineers.

In carrying out pneumatic foundations an iron caisson of the form of the object required is generally used as a working chamber. The masonry carried up upon this is usually constructed within an iron sheathing, which serves to protect the new work from injury by friction as it is pressed down into the ground, and also acts as a cofferdam. The caisson and the sheathing remain permanently in the structure. Many attempts have been made to lessen the cost of this system, caused by the loss of the iron. Works have been carried out in which the caisson served only as a diving-bell, and was afterwards removed; but this method, apart from its great cost, only answers where the foundation does not go deep into the bottom, and then only for special cases.

In another direction saving of cost has been sought by removing the upper iron sheath after the masonry has been carried up sufficiently high, and using it again.

Already in 1851 Pfannmüller had suggested in a scheme for bridging the Rhine at Mainz that the upper portion of the iron sheaths for the piers should be screwed off when the masonry was carried up above the water-level, and used again at another pier. In the case of the Saltash Bridge, Mr. Brunel removed the iron cylinders, 37 feet in diameter, for the whole depth of about 56 feet, in which the piers were not imbedded in the bed of the estuary. In constructing the Antwerp quays, the contractors built the masonry, which was founded upon pneumatically sunk caissons, within massive iron sheathings, which, when the masonry was far enough advanced, were unbolted from the caissons, lifted bodily, and reused at another part of the wall. As the foundation of the masonry did not go far into the solid, the friction to be overcome in lifting these sheathings was not great.

In 1882 the Società Italiana began the founding of a quay-wall, about 220 yards

in length, along the corrected course of the Tiber for the protection of the Villa Farnesina. The work was all done in the dry, the great curve of the Tiber not being cut out till later. The wall was founded upon a series of iron caissons, 65 feet 7 inches long, 15 feet 9 inches wide, and 29 feet 6 inches deep. The masonry was brought up for 23 feet in rough tufa and puzzuolana-mortar, and for the remaining 6 feet with a facing of travertin blocks.

A sheathing of unusual construction, which was put up to its full height at once, was used, perhaps, rather as a protection during the sinking for the rough masonry in slow-setting mortar, than as a cofferdam in which to build the upper masonry. This sheathing consisted of vertical iron plates 23.6 inches wide, connected together by two flat bars riveted together, between which the edge of the plates was pushed. There was no filling or caulking of the joints, and no attachment to the caisson. When a length of walling was finished, the plates and bars were pulled out and used again in another length.

Inspired by these works the author designed a "foundation mantle," which easily takes to pieces, and is adaptable to any form of caisson. It consists of vertical plates, 0.2 inch thick and 2 feet 7 inches wide, in 6 feet 7 inches lengths, joined together at the horizonal points by double coverplates and a double row of bolts. Laterally these plates are kept in position by fitting in a riveted ⌶ formed of two bars, 5.9 inches×0.47 inch, separated by a bar, 2 inches×0.27 inch, all three being riveted together. The vertical plates are not fastened to these ⌶ irons, but the joint is caulked. The ⌶'s break joint with the plates, and are only lightly attached to the caisson.

In the winter of 1883–4 the two abutments and two piers of the bridge over the Wisloca at Dembica, in Galicia, were erected upon this plan. The area of the ofundation of the abutments is 68 square yards each, and of the piers 57 square yards. The foundations varied in depth from 20 to 26 feet below low water, and from 28 to 37 feet below the ground level, and four or five rows of the movable plates were used according to circumstances. The materials sunk through were sand gravel first, and lower, stiff clay. When the foundation of one pier was completed and the masonry brought up high enough, the sheath was removed to the next pier. It was used four times.

To obviate any danger of bolt-heads or rather projecting pieces catching on the masonry as it is being drawn out, the space between the sheath and the masonry is filled with sand as the latter progresses. The sheath is removed by windlasses, which draw out the vertical plates and fish-joints one by one. The joint between the sheath and the caisson is simply broken in this operation.

The weight of the sheath, including all joints and fastenings, is for the lowest row of plates 19 lbs. per square foot, and for the rest 15.6 lbs. If the plates have to be re-used over a caisson of different shape from the one from which they are being taken, it may be necessary to bend them to the required curve, and to this end they must be of the best material; the vertical fish-joints are the same for all shapes of caisson.

It had been intended to make careful tests to ascertain the amount of friction encountered in drawing off the sheath, but the floods of June, 1884, made it necessary to get the work done as soon as possible, and the tests were therefore confined to the right pier, which was 115 feet from the bank, and founded 21.6 feet below low water and 38 feet below the surface of the ground, made up of—

Sand and clay	10.50 feet.
Loose stones and sand	18.60 "
Firm clay	8.90 "

While the sinking of one of the caissons was in progress, the giving way of the joints of two of the vertical plates at their joining with the caisson, gave the opportunity of calculating the external friction, the bottom of the caisson being at the time 5.2 feet below low water, and 23.3 feet below the surface of the ground. This gave a resistance due to friction of 5.1 tons per foot run of circumference, equivalent to 492 pounds per square foot of surface of the sheathing.

These and some observations of other plates which gave way on the further sinking of the caisson, taking into account the degree in which they followed the caisson or stayed behind, showed

that the earth-pressure on the inside of the sheathing is proportional to the friction just as is the case on the outside.

These slight observations showed that the coefficient of friction inside is at least as great, if not greater, than that outside, and that therefore passive earth-pressure produces as great an amount of friction as active earth-pressure. It was now of interest to determine the resistance to friction when both surfaces of the sheathing were sliding, as is the case when the sheathing is drawn off, instead of only one as in the former cases, and whether, as must be theoretically assumed, the resistances work simultaneously on both sides of the plate, and are thus proportional to the sum of the inner and outer coefficients of friction. If this is so a comparison of the theoretical calculated outside friction with the observed resistance to the drawing up of the sheathing should show the former to be at most one-half the latter.

The calculations have been made for all the cases in which the plates were above water (there being no theory giving useful results for material permeated by water).

The theoretical earth-pressure was determined by Rebhann's Construction in which the weight of the material was taken at 98.3 pounds per cubic foot, and the angle of repose for sand with loam at 38°, and gravel and sand 36°. After a long series of observations the coefficient of friction for the outside was found to be 0.466, and for the inside 0.588, or 20 per cent. greater than the outside friction. The results of the calculations were reduced to diagrams which thoroughly proved that with the simultaneous action of two surfaces of the same body (as in the case of the sheathing when being drawn off), the resistances to friction act simultaneously on the two surfaces, and therefore must be added together.

a.	*b.*	*c.*	*d.*
	Mean Resistance to the Wind'g up of the Vertical Plates of the Sheath'g.		
Depth below Surface of Ground in Meters.	Per Plate 2 Feet 7 Inches Wide.	Per 1 Meter of Circumference of Sheathing.	Per Square Meter of Sheathing.
	Tonnes.	Tonnes.	Kilograms.
1.0 (3.28 feet)	0.140 (0.138 ton)	0.177 (0.053 ton per ft.)	177 (36.3 lbs. per sq. foot.)
2.0	0.560	0.709	354
3.0	1.390	1.759	586
4.0	2.620	3.316	829
5.0	4.560	5.772	1,154
6.0	5.550	7.025	1,171
6.5	6.290	7.962	1,224
6.75	7.290	9.227	1,367
7.10	9.150	11.582	1,631
7.50 (24.6 feet)	11.310 (11.13 tons)	14.316 (4.295 tons per ft.)	1,908 (391.1 lbs. per sq. ft.)

The above table refers to the land pier on the right bank of the Wisloca. From this table it is seen that the friction at considerable depths, and especially where the earth is saturated with water, increases very rapidly. The mean water-level in the case of the pier to which the table refers was about 4.7 meters (15.4 feet) below the surface of the ground. The observations and calculations described in the paper were made by Mr. Adolf Titze, who was the engineer in charge of the works on behalf of the firm who built the bridge, the author of the paper being a member of the firm.

THE INJURIOUS EFFECT OF A BLUE HEAT ON STEEL AND IRON.*

By C. E. STROMEYER, Assoc. M. Inst. C.E.

From "The Engineer."

It was stated that, in spite of the many excellent qualities possessed by mild steel, and in spite of its extended use for shipbuilding and for marine boilers, many engineers considered it a treacherous material. They were able to adduce numerous instances in which steel plates and bars had failed, in their opinion, in an unaccountable manner. In nearly all such cases a cursory examination brought out the fact that the plates in question had been subjected to bending or hammering while hot, and there could be little doubt that while they were being worked these plates were at a blue heat, or as smiths and boilermakers termed it, a black heat. It should by this time be well known that such treatment was the most injurious to which steel could possibly be subjected, and therefore such failures could not be properly regarded as unaccountable. Iron possessed the same peculiarity, but being less ductile than steel, similar failures were not so glaring

The author then mentioned cases in which plates, both of iron and steel, had failed without this treatment, although the quality of the material was good, according to the usual tests. Three hundred and thirty experiments had been made in connection with the subject of the paper, and consisted mainly of bending and of tension tests. The results were contained in tables and in diagrams.

It appeared that the limit of elasticity of both iron and steel was raised by repeated tension testing. In some cases the limit rose above the original breaking stress, although the ultimate breaking stress was only slightly affected. The total elongation was reduced by previous mechanical operations, while the contraction varied considerably. A test piece which had been shortened when cold showed a reduction of the elastic limit, but another piece which had been shortened when hot showed an increase.

By the expression "blue heat" the author meant to include all those temperatures which produced discolorations (ranging from light straw to blue) of the surfaces of bright steel or of iron.

The author showed that steel which had been bent cold, either once or twice, would stand almost as many subsequent bends as the original test pieces. But if the same material was bent once while blue-hot it lost a great deal of its ductility. Out of twelve samples, in which two preliminary hot bends were made, nine broke with a single blow of a hammer, and the other three only stood one or two subsequent bends. Thin Lowmoor iron did not break quite so easily, but supported about one-half the original number of bends. The following Table contained some of these results:

	Medium Hard Steel $\frac{3}{8}$ in.	Mild Steel. $\frac{3}{8}$ in.	Very Mild Steel. $\frac{3}{8}$ in.	Lowmoor. Iron. $\frac{5}{16}$ in.
Unprepared or annealed	21	$12\frac{1}{2}$	26	20
Broken hot (blue)	$2\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{1}{2}$	3
1 preliminary hot bend	3 mean	$2\frac{1}{8}$ mean	11 mean	12 mean
2 " " bends	$\frac{1}{3}$ "	$\frac{1}{3}$ "	$\frac{2}{3}$ "	10 "
1 preliminary cold bend	20	$9\frac{1}{2}$	—	—
2 " " bends	$19\frac{1}{2}$	$8\frac{1}{2}$	19	13
4 " " "	—	—	13	11
8 " " "	—	—	15	6

* A Paper read before the Institution of Civil Engineers on the 16th of January.

The experiments all pointed unmistakably to the great danger incurred if iron or steel were worked at a blue heat. The difference between good iron and mild steel seemed to be, that iron broke more readily than steel while being bent; that iron suffered more permanent injury than steel by cold working, but that if it had successfully withstood bending when hot, there was little probability of its flying to pieces when cold, like mild steel.

It was a common practice amongst boilermakers to "take the chill out of a plate" if it required a little settling, or to set a flanged plate before it was cold. This was nothing else than working it blue hot, and should not be allowed. All hammering or bending of iron and steel should be avoided, unless they were either cold or red-hot. Where this was impossible, and where the plate or bar had not broken while blue-hot, it should be subsequently annealed. It was satisfactory to learn that, since the introduction of mild steel, a practice had been gaining ground amongst boilermakers, which must have the effect of guarding against such failures, and should be encouraged. It consisted in the cessation of work as soon as a plate, which had been red hot, became so cool that the mark produced by rubbing a hammer handle or other piece of wood over it, would not glow. A plate which was not hot enough to produce this effect, yet too hot to be touched by hand, was most probably blue-hot, and should under no circumstances be hammered or bent.

The theory, that local heating of a plate set up strains which sometimes caused failures, did not appear to be supported by the experiments. But it was doubtful whether the proposal to locally reheat a plate, which had been worked when hot, in order to anneal this part, should be carried out. Several test pieces were made red-hot or blue-hot, and then were slowly cooled, by holding one of their edges in cold water. As might have been expected, the medium hard steel lost much of its ductility. The other steels and the iron were not greatly affected, as would be seen from the following Table:

	Medium Hard Steel	Mild Steel.	Very Mild Steel.	Lowmoor Iron.
Unprepared or annealed	21	12½	26	20
Quenched red hot in boiling water	24	10	—	—
" " cold water	1	10	19	20
Red-hot, quenched edge in cold water	3	8	25	27
Blue " " "	3	6½	19, 19	21, 14

The author concluded by suggesting that the question should be further investigated, and that steel manufacturers should endeavor to ascertain whether every quality of steel was made permanently brittle by being worked at a blue heat, or whether this was independent of the various impurities contained in it; and also whether prolonged exposure to a blue heat could produce the same effect.

In a letter in reply to an epistolary communication of certain arguments as to the dimensions and relative distances of molecules advanced by Mr. Jules Bourdin, and published in *La Lumière Electrique*, Professor Clausius says, that the mean path of the molecules, multiplied by eight, is to their diameter as the total volume occupied by the gas is the volume occupied by the molecules; and that if the gas departs from the law of Boyle and Gay-Lussac, the departure is due to several causes, one of which is that the volume actually occupied by the molecules cannot be neglected as compared with the total volume of the gas. In order to explain the propagation of luminous waves across space, it is requisite to admit the existence of a matter susceptible of more subtle division than the ponderable gases.

THE MASSACHUSETTS DRAINAGE COMMISSION.

ABSTRACT OF THE REPORT OF A COMMISSION TO CONSIDER A GENERAL SYSTEM OF DRAINAGE FOR THE VALLEYS OF THE MYSTIC, BLACKSTONE AND CHARLES RIVERS.

SEWERAGE may be defined as the removal of what is popularly called filth, by water. For the purposes of this report it has been found convenient to consider household sewage, and the pollution of bodies of water by manufactories, separately. Confining ourselves, then, more particularly to domestic sewerage, it may be said to be largely an outgrowth of the modern systems of water supply. So long as people live thinly scattered over the country, no difficulty arises about the removal of the offensive refuse of living. It is sufficiently solid to be retained in suitable temporary receptacles for a season, and readily taken away from time to time to land, where it is valuable as manure. As long as the natural supply of clean water sufficed for the community, so long the simple natural channels of absorption and diffusion were able to carry it away when made dirty by use. Even after the inhabitants in towns became closely packed together, the same methods could be made to answer by enlarging the vaults into cesspools. It is still retained in many large places, but it requires great care in management, and considerable expense to prevent nuisance. Speaking generally it is found easiest and cheapest to use water as a vehicle for entire removal. Especially is this accepted as almost inevitable when the use of water becomes as lavish as it generally does in our towns when once a public water supply is introduced. Systematic water supply turns "night soil" into mere dirty water, which can hardly be carried away in carts, or permitted to leach away through the ground. It calls for a channel of discharge as swift and capacious as its source of supply. Sewerage works are, so to speak, the corollary of waterworks, and, in our opinion, should immediately follow their adoption everywhere. Take the city of Boston for an example, on a large scale, of what is done in miniature in half the larger towns in the State. The Mystic and the Sudbury are turned through the city at the rate of thirty million gallons a day. This enormous flood is used, and turned to sewage in the using. It must then be got rid of; but how? To answer this question in each case is the science of sewerage. The simple and obvious way is to let it run into the nearest water. This is the practice of the earliest time, and it is still admitted to be the best where it is entirely practicable. For, earnest as has been the protest of many noted theorists against this apparent waste, yet a great preponderance of evidence has convinced the best modern authorities that the loss is not a real injury. Not that any one denies that human excrement is a good manure. Nor can we controvert the chemist when he offers to prove that every ton of Boston sewage contains two cents' worth of fertilizing matter. Admitting it all, the difficulty of extracting it remains. Practically, no one would take the sewage of Boston as a gift, although in theory it may be a mine of wealth. The truth is, that the excreata and other valuable ingredients are so mixed with heterogeneous and often injurious matters, so altered by chemical changes and so drowned in water, that that they are of little or no value. It costs more to get them out than they are worth when saved. Taking all the accessible evidence into account, the very able and distinguished royal commission which lately discussed the whole question of sewage disposal in connection with the great problem of the London sewage, came at last to the conclusion that "in some very favorable cases a profit may be made without purification, and very frequently the purification may be made without profit; but the two cannot apparently be combined."

Still, though it may be true that the simplest and easiest may yet be the best way of getting rid of sewage, it

is not always suitable or safe. For, though diluted so much as to be valueless, it is not diluted enough to be harmless. It retains a facility for decay which makes it an offensive and a dangerous neighbor, and that, too, whether we cast it into the sea, or into estuaries or rivers or brooks. The defilement is often such as to cause alarming mischief. It may answer very well for New York to discharge her sewers directly into the Hudson and East River on either hand, or for St. Louis to drain straight down into the Mississippi at her feet, or for Chicago to lead her sewers into the lake under her very nose, but Boston found that it would not do to use her harbor, spacious as it is, for a cesspool; and London, after having spent twenty millions to empty her sewers ten miles below her on the Thames, now finds even that remote outlet so intolerably offensive that it must either be pushed on to the open sea, or some means of purification before discharge must be resorted to. Nevertheless, if it can be done effectually and finally, it is undoubtedly cheapest and best to cast the foul water entirely away into a body of clean water so large and so free that all trace of the contamination speedily disappears.

But when the situation does not admit of this disposition—and this condition may result from a lack of a good outlet, as well as from mere distance from the water itself—we are brought to the discussion of the other systems of disposal of sewage which have obtained the greatest degree of acceptance among professional experts and practical engineers.

First among these are two plans for using earth in much the same way as we have above described water to be frequently used. One of these schemes insists more upon the manurial value of sewage, the other looks only to its purification. The former is known as Broad Irrigation. By this process, the sewage being conducted to land prepared for the purpose, is suffered to flow over it and be taken up in part by the crops raised upon it. In short, it is an attempt to extract the element of value from the sewage by using it as a fertilizer in farming. The noxious and offensive elements are thus either beneficially appropriated by crops, or are detained in the soil by mechanical filtration, or, by long and repeated exposure to the air are decomposed, oxidized, and changed into harmless matters, so that the water which runs off is comparatively pure. More than one hundred towns in England employ this system, and it proves eminently satisfactory where conditions favor its adoption. Its great drawback is the vast area of land required for its successful operation on a large scale. It is stated, for example, in our engineer's report, that Boston would require a farm about as large as the entire township of Brookline, if it wished to realize the whole farming value of its sewage. The best English authorities estimate that one acre of land must be set aside for each one hundred persons. When it is remembered that this land must all be tolerably level and fairly dry, some appreciation is reached of the obstacle which this incident presents to the general adoption of this system. There are subsidiary difficulties which will naturally occur to all. It suggests alarming possibilities of farming on a large scale, by municipal corporations. This prospect may well damp the enthusiasm of many who would eagerly welcome such a solution of the sewage problem, if sufficient private farming enterprise were available upon tracts of land convenient and adapted to the purpose. If only the farmers stood ready to take all that might come in every hour of the year, the case were simple enough; but here lies the difficulty. This system proper does not contemplate running to waste any part of the sewage. And this circumstance is important because any elasticity just at this point would materially accelerate its welcome in New England. For weeks, and sometimes months, of our summer droughts, this dirty water charged with stimulating substances might be invaluable to men who had learned how to use it to best advantage. But that is not the proffer which we have to make when we lay out an irrigation farm. Dry or wet, night and day, summer or winter, the same quantity must be taken, or, if there be any variation it is likely to be most when the crop needs it least. And it is this obligation which we fancy would dismay our farmers. But in the absence of such a private demand, it is difficult to see how

the work can be carried out without the direct intervention of the municipality. Now, there are manifest and weighty objections to superadding such delicate functions to the already onorous duties imposed upon our town and city governments. Even apart from the consideration that they seem already sufficiently burdened, it is not probable that such management could be made tolerably economical in the long run, to say nothing of any profit, but it may be said that such a farm ought to command a rent, if there is really value in sewage. Possibly this may turn out on trial to be the case. The farm at Pullman is asserted to have more than paid expenses at times. but we have no evidence as yet that private capital is convinced of the practicability of making a profit from such a contract, and even if it were, tenants of such farms would require vigilant watching lest they turn away unwelcome sewage into the nearest water-course.

In fine, we believe this system to be admirable, if only a number of somewhat intractable conditions, some of which we have indicated, can be controlled. Where all things can be made to work together in harmony it offers a reasonable probability of at least reducing the expense of getting rid of sewage to a minimum Where an arrangement can be made to operate it in combination with filtration, so that private agriculturists may take the sewage in such quantities, and at such times as they may find best for their crops, and when not desired can turn it upon filter beds, we think there would be a fair prospect of attaining the largest measure of utilization with the least possible complication and expense.

The second of these plans is known as as Intermittent Downward Filtration through porous land. Intermittent filtration, pure and simple, is the converse of irrigation. The latter is the mininum quantity of sewage applied to the maximum area of land, and permits utilization, as well as purification to the greatest degree. The former is the application of the maximum quantity of sewage upon the minimum area of land. It permits of only partial utilization, but in our opinion of more perfect purification. It frankly abandons all dreams of profit, and in so doing it gets rid of the two greatest drawbacks to the system of irrigation. Having no crop to consider, much less land will suffice, as it is found that the ground will filter ten times as much sewage as any crop upon it can profitably absorb. Having no farming ventures at stake, we are relieved of all the machinery of trade and difficulties of management. Purification, not profit, is the paramount idea. Not that it is impossible, in certain cases, to combine some profitable use with this primary intention, but if so, it is a purely secondary consideration. This system is, in effect, nothing but turning certain tracts of suitable land by skillful preparation, into monstrous filters. There is properly no attempt to save any matters held in suspension or solution in the sewage. The object is to get clear of them utterly, whether they be good or bad, precious or worthless, and restore the water to its first estate, pure and undefiled as it bubbled from the spring. And this wonderful transformation is confidently asserted to be brought about by a faithful application of the filtration process. Its advocates maintain that sewage passed through ten feet of prepared earth is good enough for any purpose, and they claim it to be nature's process, and intimate that, after all, it is a mere question of a little more or less remoteness, and every drop of water on earth to-day was sewage not long ago. However that may be, it is sufficient for the present purpose to say that if properly managed it does afford a practicable, economic and efficient means of cleansing sewage. The objections to it are fivefold. It is charged to be wasteful in that it feeds no crop. There is a dread lest so much sewage on so little land should cause offence, especially in midsummer. Doubters are confident that the land must eventually clog. And, finally, it is thought that the cost of the preparation of the land will be excessive, or that the carelessness to be bargained for with ordinary management on a large scale would render its success utterly problematical. The final arbiter of all such questionings is experience, and that infallible test has decided that these fears are for the most part groundless. The first cost of preparing the land is doubtless likely to be considerable, but as so much less land will answer the purpose, there is found to be a large saving on

this head over broad irrigation. If thoroughly prepared, the filter will not clog, provided it be used intermittently. And finally, as to management, it has been found possible to insure care enough to avoid all offence in many places in England for many years. To the impeachment of waste it pleads guilty, urging only in mitigation, firstly, that it is entirely susceptible of modification, with a view to partial utilization; and secondly, that it can easily and advantageously be used in combination with farming enterprise, and is indeed an indispensable safety valve of that system in almost all cases. Finally, we ought to notice the prophecies of disaster which have been widely disseminated hereabouts, founded upon the alleged utter incompatibility of either of these systems with the violent extremes of the New England climate.

It is urged with great force that Old England and New England differ too diametrically in their climates to admit of safe comparison. The skeptics point out that England's atmosphere is moist and equable, while our heats are tropical and our cold arctic; that one-half the year our land is frozen solid and the other half baked hard; that in summer the sewage will stink insufferably, while in winter it will freeze into dirty icebergs, which spring will convert into torrents of sludge and filth. Once more we fall back upon experience. At Pullman, where it is colder than in most parts of Massachusetts, the frost never prevents the flow and absorption of the sewage; and the hottest days of July and August the primitive filter-field at Concord is never a nuisance, nor the lawn at the Worcester Hospital an annoyance. The sewage is warm, and melts its own way into the earth when the frost is hardest; and, no matter how hot the air, the earth has a wonderful power of deodorizing and destroying the harmful elements in sewage. This property has been so abundantly manifested in a multitude of instances, here and elsewhere, that we feel that we take no undue risk in dismissing the climatic bugbear as a chimera. We have then no hesitation in recommending the adoption of this system where for any reasons broad irrigation is impracticable or undesirable and the ocean unattainable, and we think it likely to prove always a valuable auxiliary, in combination with irrigation, where the surroundings admit of its introduction.

Processes of Deposition or Precipitation.

There remain to be noticed a number of operations with sewage which are all based upon some application of the principles of deposition or precipitation. By allowing the suspended matter to settle naturally, or by intercepting it by artificial strainers, it is possible to extract a certain percentage of it. But neither of these processes has been yet proved to work well in practice with large quantities of sewage. They are now usually supplemented by chemical treatment. The addition of lime is most generally approved for this purpose, but a multiplicity of other substances has been tried with various success. As a business venture purely, we doubt whether any scheme has proved lucrative. The resultant sludge, however manipulated, does not seem to make a highly-prized fertilizer. But a complete review of the attempts to extract the treasure from sewage would exceed our limits. Our concern is merely to make up our minds whether we ought to advise the trial of any such device upon any part of our territory. Waiving all claims which may be made in favor of these processes, as profitable or at least inexpensive, let us inquire exactly what can be expected from them, and at what cost. And here we can do no better than to condense and adopt the conclusions of the royal commission upon this head, to whose voluminous and exhaustive report reference has been made before. They tell us that "a chemical precipitating process does two things; it effects improvement in the liquid flowing away, and it leaves behind a precipitated deposit which has to be disposed of."

"The main object of a chemical process being to purify the effluent, the first point of inquiry is, to what extent does it answer this end?"

"No one denies that the suspended matters may be almost entirely removed, and therefore the clarification must effect a great improvement." It is also the general opinion that chemical processes in their best form will have some effect in removing noxious matter in solution,

but all agree that a considerable amount must be left in the effluent. This, however, may be safely discharged into a running stream, if its proportion to the supply of pure water does not exceed five per cent. But we have still to deal with the precipitate—about fifty grains, we will say, to the gallon. It is very offensive, and not valuable. By subjecting the sludge to methods of pressure, however, most of the water has been expressed without offence, and its weight reduced to about one ton to one hundred and sixty-five thousand gallons of sewage. It is possible that some market value might attach to this residuum in some localities, but we dare not count upon anything better than gratuitous removal. Finally, the cost of the operation in England is estimated to be just about one shilling per head, or, say, twenty-five cents here for each person yearly. This does not include interest on the capital invested in the works, land, and so on. By itself, therefore, it does not appear to be financially attractive.

The processes of precipitation can, like the other methods of disposal which we have briefly discussed, be combined to advantage with some one or more of those others when the circumstances favor or require it. For instance, precipitation may be supplemented to advantage by application to land. The clarified but imperfectly purified water can be used for irrigation, or passed through a ground filter, which effectually and finally removes all trace of taint or stain. By this means all desirable results can be accomplished. In case of towns on tidal rivers, this plan may be resorted to with advantage to clarify the sewage before ultimate discharge. It was somewhat considered in connection with a part of the Mystic system, but it was more expensive than the plan finally adopted, and we have not thought it expedient, upon the whole, to try any of these methods in any case with which we have been called to deal. But it may very possibly prove of service in the hand of the authorities of some towns, who may be searching for a combination which may permit the discharge of a comparatively small amount of partially clarified sewage into estuaries, creeks, or small streams.

To sum up, we are of opinion, upon the whole—

1st. That when it can be done unobjectionably, it is best to throw sewage into great quantities of free water.

2d. That filtration on land, either alone or in combination with one or more of the other processes, ranks next.

3d. That when irrigation is especially favored by circumstances, it is better than either of the preceding; but that it is so seldom that these circumstances can be controlled to advantage, that we assign to it a third place only in practical usefulness.

4th. That precipitation and chemical treatment may be advisable in connection with either of the first, second or third of these devices, but in our present state of knowledge ought not to be preferred to either of them.

Although we have preferred to treat of these fundamental propositions of the science in connection with one branch only of the subject, it is not to be inferred that we are inclined to admit any inherent distinction between household sewage and the pollution of water by other instrumentalities. Chief among these is the contamination caused by the use of water in manufacturing processes, and the incidental damage to the purity of water resulting from the establishment of great industrial activities upon streams and rivers. But while the injury done is not essentially different, there are some peculiar considerations bearing upon this part of our problem which should not be overlooked.

Manufacturing.

Manufacturing industry has from the earliest days been greatly favored by the law-makers of Massachusetts. To foster and encourage it they long ago substantially dedicated the unnavigable running waters of the land to its use. Believing its prosperity essential to the common welfare, the Legislature has not hesitated to step to the very verge of its constitutional power to stimulate and maintain it. For more than half a century persons have been authorized by law to dam up streams, and flood lands of others, for their own private manufacturing ends. This taking of one man's property against his will for the individual benefit of another has been justified

as a proper exercise of the prerogative of eminent domain, on the ground of the advantage inuring to the public from the improvement of water power, and the importance of encouraging manufactures. It has been supported, also, upon the principle which permits the State to compel the several possessors of a common interest, which they cannot beneficially enjoy in severalty, to submit to measures essential to secure a full and profitable use of their property.

As a general proposition of law it is laid down that the owners of the bed and banks of a stream have the right to use the running water in common from its source to its outlet. Each one has an equal right to its reasonable use as it flows by his land. This right of each is limited by the like right of every other. But this special qualified property of the individual in the water does not seem to exclude a general paramount interest which the public retains. Consequently, while no one can justly diminish his neighbor's enjoyment by greatly vitiating the water during his own short-lived tenure of it, neither may he destroy or gravely impair the public property in it. The factory or the mill may temporarily monopolize the flow, but they do so under an implied agreement not to spoil the water for the ordinary uses of the people in general. If they pollute the stream unduly they violate their license, and may be compelled to abate the nuisance they have made. But while it is easy to lay down the principle, it is not easy to insist upon its rigid application, without danger of working injustice and of frustrating the immemorial policy of the Commonwealth. An inflexible enforcement of a rule forbidding any defilement whatever might ruin many mill-owners and stop half the water wheels of the State. Some diminution of purity is inevitable, and tolerable, while other contamination is unnecessary or excessive. The difficulty lies in distinguishing the legitimate from the destructive usage. A satisfactory definition is impracticable. Each case differs a little from the next. The circumstances may be utterly unlike. All will agree that some kinds of corruption may reasonably be sharply dealt with. No one, for example, pretends that he can rightfully pour human excrement and household filth into the water below his dam. Neither can he justify dumping into the river waste and refuse and garbage. On the other hand, the most exacting purist might not care to complain of the sediment washed from some bleachings or scourings, the slight taint of certain kinds of harmless chemicals, or the evanescent stain of dyes which are not unwholesome. The task is to discriminate the variety of shades of impurity which occur between these extremes.

Then there is a class of cases where it may be an open question whether it is not for the public interest to abandon a stream or sheet of water to the customary pollution of industry, so long as it does not imperil the public health. Unless this be admitted, the alternative may be to drive away thriving communities, and destroy the work of years of patient labor and active enterprise, undertaken under a presumed security of tenure. In such a dilemma, if the water is not required for drinking purposes, a considerable contamination may be suffered without inordinate inconvenience. No doubt the State cannot entirely escape responsibility, even by such a relinquishment as this. The public have a right not to be poisoned by the air they breathe any more than by the water they drink. There is a foulness which is inadmissible even in a factory stream, which may embitter the life and undermine the health of the dweller upon its banks. In such cases the State is bound to intervene peremptorily if the riparian owners remain obstinately deaf to the public protest. Generally, however, before this stage is reached, the dirt of the earlier usage has so impaired the value of the water for some subsequent taker that he insists upon an abatement of the abuse above him. Complaints frequently reached the commission that this mill or that workshop so befouled a stream that fabrics which formerly could be washed white, now came out stained and damaged. Time was, they told us, when the river water was pure enough to drink, and served perfectly well all the manufacturer's purposes. Now, the sediment it carried clogged and corroded tubes, ruined boilers, caused constant foaming in making steam, and was a perennial source of annoyance and injury in their business. And upon inspection we

would find that probably the next man below our informants would echo the same complaints, attributing his troubles perhaps to the very persons who had called us in. And so on, sometimes for many miles down the stream, each successive proprietor would bewail the wretched usage which it had suffered before it reached his dam, and then proceed forthwith to give cause for more lamentation to his neighbor below. Still they cannot entirely disregard such remonstrances. Generally the moral as well as the legal obligation of abstaining from all avoidable vitiation of the water was frankly admitted, and the practice was usually deplored as inevitable rather than defended as right in itself. We are sanguine that a co-operation of water owners might be brought about, in most cases, by any board charged with the duty of mitigating the pollution of rivers, provided some practicable plan be proposed and presented to them. And we are inclined to look upon this interaction and mutual concession as likely to promise better results than a sharpening of the edge of the law. At all events we should like to see the experiment tried before resorting to harsher measures. We prefer to encourage the individual to voluntarily improve his own and his neighbor's property, and thus subserve the public interest at the same time, before we invoke the heavy hand of the General Court to coerce him.

We think it will be enough for the present to require that water for dwellings must be protected from ever avoidable taint, while water for business must not be offensive or dangerous. All wanton ill usage, such as privies over the stream, or cesspools draining into it, may well be put a stop to; and where the incidental injury characteristic of an industry is detrimental to the next user or to the public, it should be scrupulously restricted to absolutely unavoidable dimensions by the adoption of the most approved methods of remedial treatment.

But even if it should be thought expedient to impose some such restrictions as we have indicated, there is still room for much difference of opinion as to the best method of enforcing whatever regulation is adopted.

There are several ways which naturally suggest themselves. We may leave the landowners, the waterowners, and the community at large to the ordinary courts and to the common law to define and protect their various interests, or we may erect a special tribunal and prescribe by statute the scope and method of its oversight and jurisdiction, or the Legislature may pass upon each case as it arises. For reasons which we state in another place, we are inclined to recommend that the supervision of matters pertaining to water supply, sewerage, and and the pollution of waters generally, be assigned to some board which shall be clothed with powers analogous to those of the Railroad Commissioners and Harbor Commissioners, to enable it to introduce system and method in these important departments of the common welfare.

As we have extended our reasons for this provision somewhat at length in a subsequent portion of this document, we do not deem it worth while to enlarge further upon it in this place, except to point out that the function of such a board should be supplementary and not subversive of the processes, jurisdiction and rules of the common law, and the ordinary courts of justice.

After so tedious a disquisition upon the more abstract and theoretical side of the task assigned us, we recognize the obligation to hasten to present some concrete results. But, before entering upon the practical application of the general principles of sewerage science which we have very inadequately sketched, it will tend to simplify the body of this report if we can dispose of three preliminary matters at the outset. Naturally, during the long period that this question of sewerage has been impending, many projects of more or less value have been propounded, and more or less debated in the daily papers and elsewhere. There is only one of these which we deem it advisable to try to dispose of here, in order to clear the way for any really useful discussion of measures of relief. It has been suggested that the State should build a trunk sewer from Worcester to the sea, at Boston, and thus furnish the whole intervening territory with complete facilities at a blow. This scheme we consider to be entirely visionary and impracticable, for various rea-

sons. In the first place the engineering difficulties are very great, although not absolutely insuperable. As the heights of land between Worcester and Boston run north and south, separating the valleys of the Blackstone Sudbury and Charles, several long and deep tunnels would be necessary, but it is possible to bore them. Then, as a sewer once let down cannot be got up again without pumping the sewage, it becomes necessary, in covering so great a distance to maintain a steady downward grade of a very slight and regular inclination for each mile. This aggravates excessively the difficulties of location and, by consequence, greatly stretches out the length of the route. It is is not probable that a line could be found less than fifty miles in length. But even this does not put it beyond the bounds of possibility. Then, in consequence of its meandering course, which must be governed by topographical considerations, and could not be modified to meet requirements of population. it cannot be carried from town to town like a railway, but must wind from hillside to hillside. This might, and probably would, compel towns not actually touched by the main sewer to spend more money merely to reach it than they would have to pay to treat their own sewage for themselves near at hand. Still it would be possible. All these objections are serious, but not absolutely conclusive. What we do consider, however, ought to be entirely conclusive, is the enormous cost of such a work. We do not believe that it could be completed and put in operation for less than eight millions of dollars. And when it was done we should have a piece of machinery which could do no more and no better work than can be obtained from simpler mechanism for one-eighth of the money.

A second preliminary of an explanatory character may be excused in this connection. We found, after many trials, that it was impracticable to equalize the accessibility of our trunk sewer to the various communities it was intended to serve For example, take Medford and Malden, in the Mystic system, and compare or contrast their relations to the main sewer, as respects convenience of contact, with the position of Stoneham or Woburn. In the former, the main trunk runs its whole length through the most crowded population, and in streets where it actually supersedes the necessity of building town sewers, while in the latter only one not very convenient point of excess is furnished, and that so placed as to rather increase than diminish the length of local drainage. But, inequitable as this may seem, it was manifest, upon a full comprehension of all the surrounding circumstances, that it was one of the inherent and essential infelicities of our problem. And we were forced to come to a distinct understanding that we could not undertake to do more in any case than to furnish one suitable mouth or sink in each town, where it could empty its town sewers into the district sewer. One only could be granted as of right, more must be attributed to fortune of situation.

A third obvious but prudent warning may also find a place here. In none of our sewer plans has any provision been made for storm water. We do not provide for surface drainage. Situated as we were, it was found to involve a scale of cost which seemed to us entirely inadmissible. It may answer very well when sewage flows freely away into large bodies of water, but if it requires pumping, treating, or handling in any form, the accession of rainfall swells the discharge at times to utterly unmanageable proportions, and in any aspect is very costly and cumbrous. We think that the figures which we have to present will be sufficiently imposing without one dollar of needless expenditure. In our view the treatment of street scour as sewage is a luxury rather than a necessity of municipal life, and it seems to us that most of our towns and cities find that their necessities will probably absorb all the funds which they are quite ready to spare.

In the works on the Derwent Valley, Tasmania, Railway, there has been, an Australian paper says, an extraordinary muddle. It states that the recent floods carried away a large portion of the line, owing to the culverts being too small. Three different plans were made of one culvert, and the bridges declared dangerous.

THE BEHAVIOR OF STEEL.

From "The Engineer."

THE question as to the cause of the failures of steel boiler plates, apparently with no stress upon them, or with a stress far short of their estimated ultimate strength, is at the present time creating great interest in engineering circles. It has recently been suggested that the working of steel at a blue heat, that is at a temperature below redness, say from 470 deg. to 600 deg. Fah., may have been the cause of some failures. It is a noteworthy fact that most of the plates which have up to the present time failed in this manner have been previously worked in the fire, and this to some extent bears out the theory in question, by providing the probability that at least some portion of the plate was worked at this temperature. It has long been known that there is a certain amount of danger incurred in working mild steel at blue heat, as it has been found that at these temperatures it certainly loses some of its ductility, and in the best yards and workshops steel has for a long time been worked either red hot or cold; but at the same time it has generally been considered that, if the steel successfully withstood the ordeal of working at the blue heat, it was uninjured when it became cold, and that it retained the same good qualities as if it had been worked into its place red hot. It now appears that this is not the case, but that, at least with certain qualities of steel, the ductility existing when cold is reduced by such treatment; the alteration of ductility of course depending to some extent upon the amount of working put upon the plate when at a blue heat.

A favorite explanation of the so-called mysterious cracks sometimes occurring in worked plates has been that local heating during working sets up internal stresses by the expansion and contraction of the material, in a somewhat similar manner to that in which such stresses are produced in castings. The portions locally heated become expanded when hot, and as they are bound, as it were, by the neighboring cooler portions, and not able to lengthen, and being at the same time comparatively soft, they become upset. When these portions cool down they tend to contract, but being still bound by their neighboring portions they cannot shorten, and as they are then harder and stronger than they were when hot, they become stretched, or in other words, are put in tension with an equal amount of stress to that which would be required to produce an elongation equal to that which is caused by the contraction being prevented. It is in order to relieve stresses thus produced that recourse is had to annealing, which by raising all parts to a uniform red heat allows the strained parts to stretch or compress themselves sufficiently to relieve the stresses upon them while the metal is soft. The subsequent uniform cooling then leaves all portions without strain. This argument, however, only holds good for the production of initial stresses up to the amount which would cause an elongation equal to that imposed by the contraction of the parts; that is to say, practically the stresses so produced cannot much exceed the elastic limit, and as the ultimate elongation before rupture is over 20 per cent. it is difficult to see, if the material is perfectly homogeneous, how stresses thus produced can cause the cracks they are supposed to explain. If, however, the ductility is locally altered by the treatment which produces these stresses, so that the material no longer remains homogeneous, it is evident that in the harder or less yielding portions there will be a concentration of the stress; and if any treatment could produce such a diminution of ductility as to render the plate brittle at a particular part, then these local stresses, if set up at that part, might easily produce a rupture.

The possibility of the change or alteration of the ductility of different portions of a plate is accordingly a most important consideration. It has usually been accepted that steel is practically homogeneous, and this is generally cited as being one of its most important qualities, and one in which it excels iron as a constructive material; and undoubtedly

when the plates leave the hands of the makers, especially if they have been properly annealed, they possess this quality to a very high degree. But does this quality exist when the plates become part of a structure? Do none of the processes through which they pass, such as bending, hammering, punching, riveting, setting, etc., after their ductility? If they do, and a plate gets into a structure with one part harder than another, then as the stresses upon each part of the plate, when it becomes strained, depend in a large degree upon the relations existing between the deformation and the stress accompanying that deformation, the hardest or least yielding portion will bear a greater stress than the softer portions, that is, the stress will not be equally distributed, and this localization of the intensity of the stress takes place to the greatest extent in those parts which are hardest. Since rupture will commence when the local stress is equal to the ultimate strength, this unequal distribution of stress will reduce the strength of the structure below what it would have been if the stresses were uniform throughout. It is therefore extremely important that we should know whether any treatment to which steel plates can possibly be subjected during their being worked into the structure does alter their ductility, and the question as to the effect of working steel at a blue heat is one which requires thorough investigation, not only as to the kind of effect produced by such treatment, but also as to the amount of this effect. It might possibly be the case that a small amount of working at this temperature, such, for instance, as would occur in practice in closing a joint, may have so trifling an effect as to render it practically of no moment, while a larger amount of such working would be seriously objectionable. It should further be determined definitely whether the effects produced by such treatment are permanent, or whether subsequent annealing, or even local reheating to a red heat of the whole of the part affected, is sufficient to restore the ductility to its original amount. Another important point requiring solution is whether this property, which unquestionably is possessed by some mild steel, is inherent to all steel, or whether, as has been claimed by some steel makers, it is an accidental quality dependent upon some impurity in composition, or peculiarity in manufacture, and to which therefore other steels are not liable.

It is of course well known that hard steel, that is to say, steel containing a large proportion of carbon, is peculiarly sensitive to the variations of the rate of cooling down from a red heat, the quicker the rate of cooling the harder and more brittle it becomes, while the slower the rate the more ductile. It is this quality of "tempering" which makes such steel unfit for most structural purposes, and it is the comparative absence of this quality which has given mild steel such a commanding position as it now occupies as a constructive material. Yet even the mildest steel has its ductility and strength greatly modified by cooling. If made red hot and suddenly quenched in cold water 26-ton steel has its strength increased to about 36 tons, and at the same time its ultimate elongation is considerably reduced. The field of inquiry as to the ductility of steel should therefore be held to include not only the effect of working at a blue heat, but also the effect of the greater or less amount of "tempering" which can easily occur in practice in working plates that have to be fired; and this not only with the very mildest qualities of steel, but also with steel of from 30 to 32 tons per square inch.

Attention is also being given to this question in America, and we publish this week a letter on the subject from Mr. F. W. Dean, member of the American Society of Mechanical Engineers. It contains a suggestion that a probable cause of failure might be a one-sided or non-axial stress upon the material. The effect of such a stress upon a homogeneous material would be somewhat similar to that of the fairer pull upon a material of varying ductility, such as we have been considering; in each case the result is that the stress is not uniformly distributed, with the consequence that the breaking stress is reached in one part before the full strength is developed in other parts, so that the plate breaks down piecemeal. Mr. Dean states that American engineers are often struck with the small part which the elastic limit of the material plays in discussions amongst English steel manufacturers and engin-

eers. Undoubtedly we have got into a loose way of speaking of the ultimate strength and elongation of steel as being the most important qualities it possesses, and it has sometimes appeared that in discussions on the subject by our engineers the fact has been lost sight of that the elastic limit is a limit to the useful strength of the material, and also that it by no means follows that in advancing from mild to harder steel the useful strength is increased in the same proportion as the ultimate strength, since the elastic strength does not bear an invariable ratio to the ultimate.

The experiments quoted by Mr. Dean illustrate this point. Two sets of riveted joints were made of identical dimensions, the one being made from a steel having an ultimate strength of about 26 tons per square inch, and the other from steel of about 28 tons per square inch, the ultimate elongation in each case being about 32 per cent. in a length of 10 in., but in the case of the soft steel the contraction of area was much greater than in the other, while the limit of elasticity not only bore a higher proportion to the ultimate strength, but was actually greater in the soft steel than in the other. The efficiencies of these joints, although they were identical in design, were in every case in favor of the softer steel, and their greater efficiency almost exactly counterbalanced the less original strength of the material, so that a structure of the 26-ton steel would have about the same strength as one of the 28-ton steel. Mr. Dean accounts for this by the softer steel being able to yield more when under great tension, and thus to allow the stress on the material to be more uniformly distributed, the yielding being continued longer in the case in which the elastic limit is higher than in the other.

The loose way of speaking of the ultimate strengths of materials as found by a testing machine, as though they were the actual strengths of the same materials when forming part of a structure, has no doubt arisen in part from the very common requirements of specifications as to these strengths; but it should not be overlooked that the tests which have become recognized as standards of excellence do not necessarily represent the strengths of the materials as actually applied in a structure. For instance, it is usual in specifications for cement to require samples made in a particular way to withstand certain tensile stresses, yet practically the cement in structures is never exposed to tension at all. So also with regard to steel plates, they are invariably specified to be able to withstand certain tension and elongation tests, even although they are to be used for furnaces in steam boilers, or for the compression members of a bridge, in which cases they will never be exposed to tension at all. Again, the so-called "temper test" to which steel is subjected is representative of a condition to which the material in all ordinary structures is never subjected, yet this is rightly looked upon as one of the most useful tests that can be applied to steel. The fact is, that steel, like other materials, is possessed of certain all-round qualities, and if some peculiarity in its composition or manufacture affects one of these qualities it will in general affect the others as well; and as in framing specifications it is necessary to fix some points of excellence which are capable of easy and exact determination, the ultimate strength and elongation and capacity for withstanding bending being those properties which are most readily determined, are usually those which are specified with precision. It is in this way that the ultimate strength becomes generally spoken of as the strength of the material, and the elastic strength, or useful strength, becomes lost sight of. The elastic limit, moreover, is not so easily and accurately determined as is the ultimate strength. Engineers are not even agreed as what should really be considered as the elastic limit, but there is reason to believe that in the immediate future more importance will be bestowed upon this point, as there are now trustworthy autographic indicators applied to testing machines, which, if they do not definitely record the actual elastic limit, at least record quite clearly the breaking-down point, which is not far removed from that limit. As these instruments become more generally known, it is probable that they will come into more extended use, and we shall then have specifications fixing not only the ultimate strengths, but also the elastic strengths of the material. If such a practice ever becomes general, we shall still have to remember that the useful

strength is not necessarily the elastic strength, as the useful strength must still depend upon the distribution of the stresses upon the section. The uniform distribution of such stresses is principally a question of workmanship, but even with the best workmanship, it is also dependent upon the proper choice of materials. Forms which are complicated and require much manipulation to obtain accurate fitting of the parts must be made of materials which will allow the finished work to be practically homogeneous, or else, as we have shown, we cannot insure uniformity of distribution of stresses. For such forms the mildest of steel will probably be the most suitable, while there are other structures for which steel of an intermediate strength will be an admirable material, if it possesses higher elastic strength.

While the responsibility of determining what kind of steel is the most suitable for any structure must rest primarily with the engineer, and not with the steel makers, it behoves both steel makers and engineers to investigate thoroughly the whole of the physical properties of steel generally, without a knowledge of which we cannot hope to attain to that perfection for which we all strive.

THE NAVY AND ITS PROSPECTS OF REHABILITATION.

By REAR-ADMIRAL EDWARD SIMPSON, U.S.N.

ANNUAL ADDRESS AS PRESIDENT OF THE UNITED STATES NAVAL INSTITUTE.

The Proceedings of the United States Naval Institute.

Ever since I received the notification that I had been elected the President of this Institute for the ensuing year, I have had a desire to acknowledge the compliment, and to express my appreciation of the honor that you have done me in associating me with the distinguished officers who preceded me in this office. It occurred to me that the most fitting and appriate method of doing this, and at the same time of showing my interest in the Institute, would be to prepare a paper to be read at one of the meetings, or to be published in our Proceedings. The range of subjects to choose from is very wide, for as this Institute has to do with matters pertaining to the Navy, it is hard to indicate any subject known to modern progress that would not be appropriate; but I concluded to confine myself to no one of these, but rather to assume the position of an observer of what is now transpiring, to suggest what seems to me to be needful, and to consider the prospects that are held out in the way of rehabilitation of the Navy.

I am aware that in making an address I am departing from custom, but I am willing to endure the penalty that is imposed for the sake of putting before you some ideas which I could not find a more convenient method of presenting. I have been employed lately on duties relating to ships and gun foundries, which afforded me opportunities for observation and naturally encouraged thought; and it occurred to me that remarks on these subjects, and ideas resulting from the study of them, could not be altogether without profit, and might be found interesting. I accordingly devote much of my space to these two subjects, avoiding in the latter, gun foundries, a repetition of what you have read in the report of the Gun Foundry Board, but supplementing what is therein stated by some explanations, which can be familiar only to those who were members of the Board.

I was the more inclined to address you in this manner from the fact that your notice of me and my work comes at the time when, for reasons beyond my control, I am about to be retired from active service, and will be for the rest of my life only a "looker-on in Vienna," and it is for me a suitable time to sum up accounts and, as it were, to take an account of stock.

My first associations with the Navy were nearly 46 years ago. It then occupied a very creditable position, but I saw

it advance to its zenith when its ships were the models for the imitation of the world, and its guns were the standard of excellence. I have seen it in its decline until its *materiel* has reach the point where it can be cited as the standard of inefficiency. Even our own daily press make it a target for its shafts of ridicule. Thanks to the Naval Academy and the abiding high tone of the service, its personnel is above reproach, and, in this day of the decadence of our ships and guns, it finds itself equipped for the trying work now before it.

This condition of preparation is the result of the training of officers at the Academy, where the door of knowledge was opened to them, and to their own individual efforts to advance in the studies inaugurated at that institution. This Institute is one of the proofs of the aspiration for advancement that felt the need of a field in which to exhibit prowess, and these efforts have been continued under a pressure that seemed to forbid any chance of encouragement. This element of success we were not favored with for many years; but let us view the outlook of to-day, let us see if we have not now a right to feel encouraged, and to believe that the tide, having reached its lowest ebb, is now on the flood on which we may rise to the position we once held.

The first and most important consideration for a navy are ships! A reference to our Navy List shows a beggarly account. What encouragement have we for the future? We have much encouragement, and I will trace with historical precision the progress that has been made slowly, indeed, but surely, in this directon.

The origin of the effort dates from June, 1881, when the Hon. William H. Hunt, Secretary of the Navy, appointed an advisory Board to consider and to report on the need of appropriate vessels for the Navy. This board, styled the first Advisory Board, decided that for all purposes of "surveying, deep-sea sounding, protection and advancement of American commerce, exploration, the protection of American life and property endangered by wars between foreign countries, and service in support of American policy in matters where foreign Governments are concerned," and for providing a "reserve of sufficient strength to maintain the effectiveness of the fleet," the United States Navy should comprise 70 unarmored cruisers.

The Board, in its report of November 7, 1881, stated that there were 32 vessels in the Navy fit for service. The required 38 vessels were classed as follows, viz.:

Two first-rate steel double-decked unarmored cruisers, having a displacement of about 5,873 tons, an average speed of 15 knots, and a battery of four 8-in. and twenty-one 6-in. guns; cost, $3,560,000.

Six first-rate steel double-decked unarmored cruisers, have a displacement of about 4,560 tons, an average sea speed of 14 knots, and a battery of four 8-in. guns and fifteen 6-in. guns; cost, $8,532,000.

Ten second-rate steel single-decked unarmored cruisers, having a displacement of about 3,043 tons, an average sea speed of 13 knots, and a battery of twelve 6 in. guns; cost, $9,300,000.

Twenty fourth-rate wooden cruisers, having a displacement of 793 tons, an average sea speed of ten knots, and a battery of one 5-in. and two 60-pounders; cost, $4,360,000.

In addition to these cruisers, it was recommended to build five steel rams of about 2,000 tons displacement, and an average sea-speed of 13 knots; cost, $2,500,000.

Five torpedo gunboats of about 450 tons displacement, and a maximum sea speed of not less than 13 knots, and one heavy-powered rifled gun; cost, $725,000.

Ten cruising torpedo boats, about 100 ft. long, having a maximum speed of not less than twenty-one knots an hour; cost, $380,000.

Ten harbor torpedo boats, about 70 ft. long, having a maximum speed of not less than 17 knots per hour; cost, $250,000.

The Board stated that "iron-clads are absolutely needed for the defence of the country in time of war," but as its orders were to recommend means of providing for the present "exigencies of the Navy," it considered this type outside of the category of vessels it was ordered to consider.

In the naval appropriation bill, approved August 5, 1882, authority was

given to build one each of the first two types enumerated above, and an Advisory Board (the second) was provided to advise and assist the Secretary of the Navy in all matters relating to their construction, and "to prepare plans, drawings and specifications of vessels, their machinery and armament, recommended by the late Naval Advisory Board not authorized to be built."

The second Advisory Board was organized November 13, 1882, previous to which there had been issued from the Navy Department notice and advertisements concerning the construction of the two steel cruisers, inviting "all engineers and mechanics of established reputation, and all reputable manufacturers of vessels, steam-engines, boilers, or ord nance, engaged in the business, all officers of the Navy, especially naval constructors, steam engineers and ordnance officers, having plans, models or designs of any vessels, or of any parts thereof, of the classes authorized by the Naval Appropriation Act of Congress of August 5, 1882, to submit such plans, models and designs to the Naval Advisory Board directed to be organized by the Secretary of the Navy, under the provisions of said Act, for his advice and assistance in designing and constructing said vessels, in order that the same may be examined by said Board in accordance with the provisions of said Act."

The Board issued a circular November 25, 1882, suggesting the general features for the larger vessel authorized to be built, for the guidance of those proposing to submit plans.

The Board recommended to the Secretary of the Navy, November 21, 1882, that, in addition to the two cruisers already authorized to be built, there should also be constructed two of the ten second-rate single-decked steel unarmored cruisers recommended by the first Advisory Board; also one dispatch boat.

On January 2, 1883, the Secretary of the Navy recommended to Congress (in accordance with the advice of the Advisory Board) the construction of one steel cruiser of about 4,000 tons displacement, three steel cruisers of about 2,500 tons displacement, one dispatch boat of 1,500 tons displacement, and one cruising torpedo boat, to cost $38,000. The largest cruiser previously authorized was omitted for sufficient reasons, as she could not be built on the sum appropriated, and it was not considered judicious to build so large and expensive a vessel which is not required, and which would be very expensive to retain in commission.

On February 1, 1883, the Board submitted general features for a 4,300-ton cruiser, and on February 5, 1883, the Secretary of the Navy issued the same to ship builders and engine builders in the United States likely to make proposals for construction.

Congress in the Naval Appropriation Bill, approved March 3, 1883, provided for the construction of one cruiser of 4,500 tons displacement (Chicago), two of 3,000 tons displacement (Atlanta and Boston), and one dispatch boat of 1,500 tons displacement (Dolphin), a portion of the estimated cost being voted at that time, and the balance being provided in the temporary half-year appropriation for the Navy approved July 7, 1884.

The Secretary of the Navy, in his report of December 1, 1883, recommended, in accordance with the advice of the Advisory Board, the construction of seven additional steel vessels, viz.: One of each of the three types already under construction by the authority of Congress, and in addition to them, two heavy and two light-armed gunboats. The consideration of a bill introduced in Congress in accordance with this recommendation, produced an investigation by a Senate committee, the evidence given at which showed that, with the exception of two of the officers summoned, the Advisory Board had the confidence of the Navy.

This bill failed to pass the House of Representatives. The debate upon it in the Senate was very thorough, and showed that, in that chamber, party lines were yielding to what was felt to be a national question.

In the act making appropriation for the Navy, approved March 3, 1885, Congress authorized the construction of four additional vessels, two of not less than 3,000 nor more than 5,000 tons displacement, costing, exclusive of armament, not more than one million one hundred thousand dollars each; one heavily armed gunboat of about 1,600 tons displace-

ment, costing, exclusive of armament, not more than five hundred and twenty thousand dollars; and one light gunboat of about 800 tons displacement, costing, exclusive of armament, not more than two hundred and seventy-five thousand dollars. This bill was passed during the last hour of an expiring Congress, and a line introduced in the House provided that the construction of these vessels should be under the direction of the Navy Department, not subject to the supervision of the Advisory Board. The general features and preliminary plans and calculations have been made for these vessels by a special Board on additional vessels, and they are now in the hands of the Bureaus, who are preparing designs on which bids can be made if proposals are issued for their construction by contract.

We thus see that, notwithstanding the apathy into which we had fallen, notwithstanding the more serious obstacle of party rivalry, whether with an Advisory Board or without an Advisory Board, the Navy can count on an addition of seven steel cruisers of modern construction, and one dispatch boat as a nucleus for the new Navy. The coming year will see four of these vessels completed, and it may be that the year following may launch the four additional vessels; and have we not a right to believe that, the inertia of rest being overcome, and the energy of motion having been communicated, the pressure of the wave of public opinion will grow in force until it will come to be a recognized necessity to make a yearly appropriation for the increase of the Navy? I think we have a right to believe it. We know that public opinion is with us, the individual legislator will agree to the necessity of the increase; it only remains for the rivalry of parties to be supressed in the face of this national question, and the signs are greatly in favor of this devoutly wished-for consummation.

It will be noticed that the Act of Congress which originated the first action in this matter was founded upon the recommendation of the first Advisory Board, and it is natural to suppose that the report of that Board will be referred to in future steps that may be taken, and if later experience does not suggest modifications, that they will form the basis for future action. We may thus conclude that the number of vessels indicated by that Board as sufficient to perform the duties of a navy in time of peace will be adhered to, and that seventy unarmored cruisers of steel will in course of time be added to the Navy list. I count the whole number of cruisers of steel, because, even at a much faster rate than that at which we propose to build, our present supply of wooden ships will have entirely disappeared before that number will be completed.

It will also be noticed that the first Advisory Board interpreting its instructions ("to provide for the present exigencies of the navy"), not to apply to armored vessels, made no recommendations as to the construction of such vessels, merely noting that "iron-clads are absolutely needed for the defence of the country in time of war." It seems to me that this is a weak position for us to continue to hold, that is, if the practical working out of the idea is to postpone the construction of armored vessels until we shall have provided ourselves with the seventy unarmored cruisers needed for current use. This is a short-sighted view to take of the matter. There is no good reason why the building of both armored and unarmored vessels should not be prosecuted at the same time; in fact, I think, it can be shown that the construction of the two classes of vessels at the same time would prove ultimately to be economical in result. But, apart from the matter of cost, does it not seem absurd to confine our preparations only to what is required in peace when it is openly recognized that the *armored* vessels are indispensable in time of war?

ARMORED VESSELS.

This view was actually taken of the subject by Senators when the bill for additional vessels was under consideration in the Senate in 1884. One Senator who declined to vote for the additional unarmored cruisers declared that he would vote fifty millions for vessels capable of contending with first-class iron-clads and of resisting modern artillery.

Taking advantage of this offer of the Senator, and with the earnest desire to give him a chance to vote his fifty millions, I addressed a letter to the Secretary of the Navy, which I place here on

record as I find it embodies ideas and recommendations which I still hold to be sound. The letter was as follows:

"NAVY DEPARTMENT, WASHINGTON,
April 11, 1884.

"The Honorable W. E. CHANDLER,
Secretary of the Navy.

"SIR: Referring to the debate in the Senate on the amendments to the Naval Appropriation Bill, objection is raised by some Senators to granting additional vessels to the Navy on the ground that the cruisers asked for are not of such fighting quality as to match armored vessels of other nations, the inference being that if a bill were presented for the construction of an armored vessel it would meet with their approval.

"The first Advisory Board was fully sensible to the need of armored vessels for the Navy, but in consideration of the great need of cruisers to carry the flag abroad it recommended as the first step in rehabilitating the Navy the construction of vessels to supply this, the most pressing want of the service. Construction of armored vessels was confidently expected to follow in due order after a sufficient number of unarmored vessels should have been built to form a cruising force. It seems apparent that the building of armored vessels, and of unarmored vessels, was not proposed to be carried on simultaneously, from a disinclination to call for very large appropriations.

"For the purpose of conforming to the implied desires of Senators for armored ships, and from the fact that there is no doubt of the need of them, I respectfully recommend that the programme laid out by the first Advisory Board be so far departed from as to admit of having one armored vessel under construction constantly, even while the work of providing cruisers is in progress.

"The length of time required for such constructions is from three to five years. They are very costly, and will involve much study and careful preparation; besides, the selection of a type will be a matter requiring much deliberation.

"In relation to the last point, the selection of a type, I submit general dimensions and some particulars of two armored vessels which represent the most advanced ideas of the present day. One of these would, most probably, be the character of the vessel that would be recommended by such a body as the Advisory Board.

"H. B. M. Ship Imperieuse, not yet completed, was commenced in 1881. She is called an armored cruiser, and is intended for sea service on foreign stations where fast unarmored ships may have to be opposed, and where second-class ironclads may have to be engaged. Her dimensions are as follows:

Length	315 feet.
Beam	61
Draught	25
Displacement	7,400 tons.
I. H. Power	8,000
Speed	16 knots.

"The battery will consist of four 9.2-inch guns, each mounted in an armored barbette, and six 6-inch guns in broadside. The barbettes are arranged one forward and one aft, and the others abreast of each other at the sides amidships; the heavy guns are thus situated at twice the height from the water that they would be in a turreted vessel, and can be fired three together in any direction. The speed and armament here described does not greatly exceed that of the Chicago, but the difference in displacement of 2,900 tons admits of the following armor:

"Throughout the length occupied by the machinery and boilers (139 feet), the sides are protected by ten inches of compound armor for a depth of eight feet, the deck over this is one and a-half inch thick; bulkheads of plating eight inches thick run athwartship at the forward and after extremities of the side armor, thus forming a citadel enclosing the machinery and boilers. Forward and abaft the citadel, at the level of its lower edges, extends a protective deck three inches thick, sloping downwards to the sides, as in the Boston and Atlanta. The barbettes are seventeen feet in diameter, and are armored with eight inches of steel, which protects the machinery for turning, elevating and loading the gun, and an armored chute leading to below the armored deck makes the passage of ammunition safe and rapid. The pilot tower is protected by ten inches of armor.

"Contrasting the protection afforded by the armor above stated with the vulnerability of the Chicago, the advantage

of the increased displacement of the Imperieuse becomes apparent.

"Another type of vessel that would come up for consideration is the turreted ship Riachuelo, just completed for the Brazilian Government by an English firm on the Thames. Her dimensions are as follows:

Length	305 feet.
Beam	52
Draught	20
Displacement	5,700 tons.
I. H. Power	6,000
Speed	16 knots.

"The armament consists of four 9-inch guns in two turrets, and six 6-inch guns on the upper deck. There is an armor belt of eleven inches thickness covered by a two-inch deck, and the turrets have ten inches of armor.

"The armor protection is by no means so complete as that of the Imperieuse, nor is the arrangement of the battery so effective, but on the other hand, the speed is greater and the displacement is 1,700 tons less.

"These instances are cited to show that a Board cannot, except after the most careful study and examination, decide upon even the size and general dimensions of an armored vessel best suited for our purposes; therefore, in suggesting the form for an Act of Congress which shall the best carry out the recommendation I make in this communication, and estimating the time for completing the vessel as three years, I would propose that the authority should be given somewhat in the following form:

"For the construction of one armored vessel of not exceeding 7,500 tons displacement, one million dollars; such vessel to be constructed under the same conditions as prescribed for the construction of the steel cruisers, and its armor and armament procured, at a total cost not to exceed two millions five hundred thousand dollars.

"Very respectfully,

"E. Simpson, *Rear-Admiral.*"

This letter was communicated to Senators and found its way into the press. In these days of rapid development we cannot confidently count on adhering for any length of time to what we approve to-day. The development is still going on, and the advance already made may constrain us to go a step further, but in this matter of type of armored vessel I think we can claim an exception; for I find no reason to change or modify what I wrote in April, 1884, and I am inclined to think that the question is definitely settled between the casemate, barbette and turret. The first type of seagoing armored vessel naturally had the armor disposed on the broadside. The movement commenced in France, in 1858, was followed by England, and continued until their formidable fleets were equipped in this manner. In 1868 the casemate or central battery armored vessels appeared, represented in England by the Hercules and the Sultan, and in France by the Océan, the armor being limited to an armored belt at the water line, and the protection of the battery and engines by an armored casemate. In the French ship, however, in addition to the casemate for the central battery, there were introduced four barbettes, one at each of the four corners of the casemate, armored with six and a half inch plates, and mounting in each a gun of fifteen and a half tons weight. The Marengo, Suffren and Friedland quickly followed the Océan, with batteries and armor arranged in a similar manner. Since that time the construction of casemate ships has been gradually discontinued in France, and the barbette is now the adopted type, the armor consisting of a water-line protection and an armored deck covering all vital parts, while the vertical tubular passages for the passage of ammunition are strongly protected. Apart from other reasons this arrangement of armor conforms to the necessities arising from the introduction of guns of much increased caliber and weight.

In 1872 the English Admiralty built the Téméraire, in which two guns were mounted en barbette in connection with a central battery; but they did not fully adopt the type until 1882, when the Collingwood was launched. It is evident that the advantages are fully recognized now by the English authorities, for a large number of vessels of this type are now under construction. I cite here the names and displacement of those which are being rapidly pushed to completion, viz.:

Collingwood	of	9,150 tons displacement.
Imperieuse	"	7,390 "
Warspite	"	7,390 "
Howe	"	9,600 "
Rodney	"	9,600 "
Camperdown	"	10,000 "
Benbow	"	10,000 "
Anson	"	10,000 "

This list is sufficient to prove that England thinks the barbette type of armored vessel has come to stay; such action implies no doubt of the efficiency of the system.

The monster ships of Italy, the Lepanto and the Italia, of 13,898 tons and 13,550 tons displacement, are of the barbette type, and that nation has now under construction three additional vessels of the same type, viz.:

	Tons displacement.
The Ruggiero di Lauria	of 10,045
Francesco Morosini	" 10,045
Andrea Doria	" 10,045

Russia has ten barbette ships on her Navy list, and is continuing the construction.

In recommending, then, as I do, the barbette type of ship for our sea-going armored vessels, I think I have the experience of the world to sustain me. No more positive proof can be given of the superior advantages of the system than the practical demonstration given by the nations cited of their faith in it. There is no saving of weight of armor, but the disposition of the weight is radically different from what it is in a ship with casemated battery, and is better arranged to protect all submerged parts of the vessel, the armor deck being extended aft to the stern, thus covering all parts of the steering apparatus, while forward it gives most valuable support to the ram. The only question that could arise in selecting a type would be between the barbette and the turret system, but for sea-going purposes the increased height in the disposition of the battery given by the barbette, as compared with the position of the battery in a turret ship, must be recognized as an advantage hardly to be equalled by any others that the friends of the turret could advance for their type. And even for coast defence, or for harbor defence, the barbette system presents so many advantages that it seems to be possible for it to be substituted for nearly all purposes where the closed turret is now used. This probability increases with the increase of calibre of the guns, for it must be remembered that with the turret system the port is very near the deck, and the blast from the discharge of a 100-ton gun is something tremendous. There is a dearth of experiments on the effect of blast at the muzzle of a gun. They are much needed to assist in the investigation of this very point.

Having stated my conviction that there should be no delay in commencing the construction of armored vessels, and having given you the reasons for my preference for a particular type of vessel, and believing that type is sufficiently established by the experience of the world to justify us in accepting it as a standard, I submit to you now a few of the general features of such a vessel as I would advise. It is not exclusively my own design; it is evolved from the deliberations of a body of earnest men who considered the question carefully.

I premise by saying that we are restricted as to the displacement of our armored vessels. It is impossible for the United States to utilize such a vessel as is ranked as first class by other nations; we have not a sufficient depth of water on our bars. It is a question of draught of water. Again, the dimensions of the vessel must be governed by the size of our dry docks; that building at Mare Island is the only one that would admit a first-class ironclad, while those at Boston and Norfolk limit the extreme breadth to about 58 ft. Here is an absolute limit set on two dimensions, and, confining the length to near 300 ft., in order to ensure handiness, it will be found that, combining these with the two other governing qualities of large margin of stability and space for well-protected machinery, the maximum displacement will be fixed at about 7,000 tons.

The principal dimensions of the hull would be:

Length	320 feet
Breadth	58 "
Mean load draught	23 "
Load displacement	7,300 tons
Maximum speed in smooth water	16 knots

The battery should consist of four 10 inch B. L. R. guns, each mounted *en barbette* within a fixed turret nineteen feet in diameter, one located on each side

amidships, and the other two on the middle line of the upper deck, one forward and one aft; the guns to be protected from machine fire by revolving hoods of 4-in. steel, the axes of the guns of the side turrets to be twenty-one and a half feet, and those of the middle-line turrets twenty-three feet above the load-water line.

Four 6-in. B. L. R. guns should be mounted on the upper deck protected by circular revolving 4-in. steel shields.

A suitable secondary battery should be carried, consisting of Hotchkiss single-shot guns of 57 and 47 millimeters, and revolving cannon of 37 millimeters, and Gatling guns.

The allowance of ammunition should be 100 rounds for each 10-in. and each 6 in. gun, 1,500 rounds for each large Hotchkiss gun, and 800 rounds for each 37 mm. gun.

Four hundred and forty-five tons should be reserved for the weight of ordnance.

There should be separate magazines and shell rooms for each turret.

The hull should be built of mild steel with brass stem, stern post and rudder should be cased with wood to the height of the main deck, and sheathed with copper.

The armor protection should consist of a belt eight feet in depth, three and a-half feet above and four and a-half feet below the load line, extending throughout the length of 150 feet occupied by the machinery and boilers and central magazines, the ends being enclosed by athwartship bulkheads nine inches thick, the thickness of the side armor being ten inches from the top to one foot below the water line, and tapering thence to five inches at the lower edge of the belt.

The armor on the barbette turrets should be seven feet deep and eight inches thick, on the pilot tower five feet deep and six inches thick, on the hoods to barbette guns four inches thick, and on the ammunition tubes to turrets four and a-half inches thick.

At the level of the top of the armor belt and throughout its extent, there will be an armored deck two inches thick, and before and abaft the armor belt the armor deck is continued to the extremities at the level of the lower edge of the armor belt, or four and a half feet below the load-water line amidships, sloping at the sides, and at the bow to strengthen the ram.

The ship will have such sail power as can be carried on two steel lower masts, to be fitted to carry circular tops for machine guns and extra gaffs or derricks for hoisting torpedo boats.

Provision should be made for carrying and launching two sixty-foot torpedo boats in addition to the usual allowance of boats, and the vessel should be designed with refence to being ultimately fitted with above-water launching gear, in four places, for an automatic fish torpedo.

The coal supply at load draught should be 500 hundred tons, with bunker capacity for 800 tons; and arrangements should be made to stow provisions for 400 men for 90 days, and other stores for the usual periods.

The engines and boilers should be capable of developing 7,500 I. H. P. in the aggregate, during a six-hour full power trial, the fuel to be the best semi-bituminous coal.

The fire rooms should be made air-tight, and fitted with centrifugal fans of sufficient capacity to maintain therein a pressure above the atmosphere equivalent to a column on one and a half inches of water.

There should be twin screws actuated by two sets of three cylinder direct-acting vertical compound engines, the two engines complete being contained in water-tight compartments, separated by a longitudinal middle line bulkhead.

It is proposed that the steam should be supplied by twelve three-furnace cylindrical boilers, having an aggregate grate surface of 900 square feet.

The total weight of the machinery, boilers and appurtenances, including water in boilers and condensers, all fittings, tools, stores, spare machinery, ready for sea, should not exceed 1,400 tons.

This is the vessel recommended to the Secretary of the Navy by the Advisory Board, "a part of which I was."

I believe this ship to be a sound basis to work on. Controlled as we are by nature in the displacement to which we can attain, and satisfied as I am that we have reached the type of vessel that will remain permanent, I see no reason why

we should delay commencing the construction of our sea-going armored fleet. This fleet should consist of ten vessels, forming the outer line of defence of the coast in war, always available for operating abroad either in peace or war, and affording a school of practice and instruction in peace to prepare us for war.

COAST DEFENCE VESSELS.

But in addition to sea-going armored vessels, we are sadly deficient in vessels for coast or harbor defence. We have sixteen ports on the Atlantic coast to guard, besides San Francisco and other points on the Pacific coast. For this purpose we require a fleet of heavily-armed and armored turreted, or barbette vessels, to cover the coast as a second line of defence, and to concentrate at any time at the point attacked. These vessels should be of moderate speed, but as near invulnerabe as possible, and armed with batteries that should be irresistible. Two classes of this type would be needed in order to provide for operations in shallow as well as in deep water. With the experience of others, and our own, we could easily determine upon the general features of suitable vessels for this service. The distinct duty for which these vessels would be designed would be to engage armored vessels; consequently all other considerations would have to yield to protection of the hull and the power of the guns. The heavier class should carry guns of 100 tons weight, and the lighter class of guns, say, 50 tons weight, and I consider that 25 of such vessels are needed to complete the second line of defence. The lightly armored and indifferently armed monitors that we now have on the Navy list can be utilized in the third line of defence until more suitable vessels can be provided, and in concert with systems of torpedoes, will serve as the defence for harbors and mouths of rivers.

I think that it is very desirable that the construction of the coast defence vessels should go on at the same time with that of the unarmored and armored cruisers. There is no sufficient reason for delaying in either case. As all will be ultimately needed, it is poor policy to delay the work on one until it is completed on others. The navy yards are idle; no more suitable work can be found for them than the construction of armored vessels. The shipbuilding interests of the country are at a standstill; no more appropriate or congenial work can they find to fill up the interval of stagnation than the building of unarmored cruisers. The work would give occupation to tens of thousands of mechanics and laborers, and new industries would be started in the country.

In this connection it is proper to put prominently to the fore the absolute necessity of completing at once the four double-turreted monitors, which lie in an unfinished state at the yards of the contractors. These vessels have been assailed for one reason or another, and the effort has been made to impair confidence in them. I know not how far these efforts have influenced the mind of the Navy, but in order to clear up any doubts that may exist I will quote from a report made by the Advisory Board, in October, 1883, in which the Board states its reasons for recommending the immediate completion of the ships.

The Board says: "It is our opinion that it would be wise and expedient to finish the vessels at once, and for the following reasons, viz.:

1st. The hulls as they are at present are of excellent workmanship, fully up to the present standard condition of iron-ship construction, whilst the flotation of the Puritan and the behavior of the Miantonomoh at sea confirm the correctness of the calculations of the designs.

"2d. It is easily possible to complete the vessels by taking advantage of the recent developments in armor, guns and machinery, without making any radical changes in the designs, so that their speed, endurance, battery power, protection, and sea-going qualities shall be fully equal to those of any foreign iron-clad of similar dimensions designed previous to 1879.

"3d. The vessels may be finished so as to develop all the abovementioned advantages without making their total cost when completed in any way exorbitant compared with the results obtained; again, the interests of our sea-coast defence require a force at least equal to that which would be represented by these vessels.

"We take the liberty of calling your attention to a certain erroneous impres-

sion which now exists with regard to these vessels. In one of the official reports on these hulls a doubt was thrown upon the correctness of the calculations of the Puritan. This doubt has spread in the public mind until it includes all the ships. The actual flotation of the Puritan and the Miantonomah proves beyond question, not only the reliability of the calculations, but also that the hulls of these vessels are lighter in proportion to the total displacement than those of any ironclad low freeboard hulls afloat, with but two exceptions.

"It has been the unfortunate custom, in arguments as to the value of the results to be obtained, to compare them with such foreign ships as the Inflexible and Duilio, to the evident disadvantage of the monitors, no account whatever being taken of the fact that these vessels are double the size of the monitors. If these hulls be compared with foreign ones of similar dimensions no such disparity will appear."

Here I close the extract from the report of the Advisory Board. This statement should set at rest all doubts as to the efficiency of the vessels, and the work should be resumed on them with view to their completion at the earliest practicable moment. It is well to add that five other Boards have made similar reports recommending the completion of the vessels.

These vessels, with the exception of the Monadnock, have their machinery in place, and are finished as to their hulls, except the interior fittings, side armor and turrets.

The estimated cost to complete them is as follows:

Puritan	$1,141,481
Terror	786,267
Amphitrite	797,563
Monadnock	1,074,069
Total to complete	$3,798,380

TRAINING VESSELS.

Before dismissing the subject of ships, I should mention a serious want of the Navy in the lack of suitable sailing vessels for training boys and for the exercise of naval cadets in practical seamanship. The system for training boys for the Navy is now established on a basis that seems to work satifactorily, but, singular to say, the article that is of the very first consequence is that in which we are the most deficient. The few remaining sailing vessels of the Navy are devoted to this duty, but they are so old and are so constantly in need of repair that in a year or two they also will be withdrawn from service. At best, however, they are inefficient vessels, particularly in consequence of the size of their spars and weight of sails; they are too large and heavy to be handled by boys. This objection also obtains in the case of the vessels assigned to the naval cadets. The Naval Academy and the Training School should both be provided with ships of the Dale class, composite built, full-rigged. Six of these vessels should at once be provided. They would be launched in a few months at a cost of about $175,000 for each.

Amid the pressure of advanced ideas and the earnest efforts of progress, the basis of a seaman's education should not be forgotten. Seamanship must not be neglected, and it is at an early age that the knowledge must be acquired. All old officers will agree that they learned their seamanship during their midshipman's career. Learned while young, the knowledge will remain for life and will form the source from which we can draw to our aid in all other branches. There is nothing like it for developing the power of resources and the invention of expedients. A seaman is never helpless. If one means fails he will try another. He can work without tools. The sailing of a ship, the handling of spars, the trimming of sails, the hoisting of weights, the stowing of a hold, all give him an instinctive knowledge of practical science, and above all, a seaman trained to a sailing ship acquires a degree of personal confidence which can come from no other source. We may say that we have now no sailing vessels in general service, hence the necessity of more earnest training in this branch before an officer or man is launched into the regular service. A ship combining sail and steam is not a suitable vessel for training purposes for officers or men. Sailing ships, pure and simple, must be applied to this use, or the education will be sadly deficient.

GUNS AND GUN FOUNDRIES.

The gun as the thing of next importance merits attention. How do we stand

in respect to this important element, which stamps the character of the ship, and to the efficient working and handling which all the designs of the constructor and engineer must be accommodated and made subservient?

We are fortunate in one very important point in the matter of the gun wherein our delay in commencing work has proved of advantage to us. We have adopted a type of gun which all agree is the best. There is no difference of opinion among us. We have received the Vavasseur method of construction as the one superior to all others, and we are confirmed in our judgment by that of other nations who, having embarked in other systems, have now abandoned them and accepted that of Mr. Vavasseur. Woolwich has abandoned wrought-iron, and the efforts of the steel manufacturers of England are now put to a severe test to supply steel in masses of sufficient size to answer the demand, and what is now called the Woolwich gun is the Vavasseur gun, so determined by the Ordnance Select Committee. The Krupp construction is also modified so as to include the Vavasseur long jacket; and the French, though yet somewhat divided between the plans of General Dard of the Marine Artillery, and Colonel de Bange, on whose ideas the army guns are constructed, are approaching the Vavasseur standard. The guns that we see slowly progressing at the Washington navy-yard are Vavasseur guns pure and simple.

You all know how much the matter of the gun has occupied my thoughts, and, though, for reasons beyond my control, I have not been privileged to direct in any way this arm of the service, you can readily understand what a gratification I enjoy when I see the ideas that I advanced many years ago being carried out and executed by the present accomplished Chief of the Bureau of Naval Ordnance, an officer well fitted to carry forward the work, and with time before him on the active list to perfect it. I sympathise with him in the extra work imposed upon him in having to invent expedients for manufacture instead of having at his disposal a suitable plant. I will review the steps that have been taken to supply this deficiency.

By Act of Congress, approved March 3, 1883, there was established a mixed Board of Army and Navy officers called the Gun Foundry Board, whose duty it was to take into consideration and to report on the best means of making ourselves independent in the matter of manufacturing modern cannon. It seemed to be a foregone conclusion with the framers of the bill, that the gun to be manufactured was to be of steel, and that this new manufacture could not be performed by the means at the disposal of the country, which had, up to the time of the Act, manufactured guns only of cast-iron. The Board was not called upon to deal with the matter of gun construction; its province was to recommend suitable sites, tools and all apparatus for the manufacture of guns, and to submit the approximate cost. In the early part of its labors the Board could derive no assistance whatever from our own steel manufacturers. They had not taken the matter into consideration, they possessed no tools calculated to do the work required, none such were made in the country, and the capacity of their furnaces and forging apparatus was insufficient to cast the masses or to forge the ingots required. The information required was gained abroad, and I do not propose to repeat to you the contents of the report made on the subject to Congress. The report has been widely circulated in the Navy, and it attracted much attention from the steel manufacturers at home—so much so as to remove the wall of partition that seemed to exist between them and the Board when they were first approached, and to cause them to come forward and assist the Board in the preparation of its supplementary report, which was called for in order to present in detail a method by which the recommendations of the Board in the original report could be made a practical thing. The plan proposed by the Board for putting in execution its recommendations is the basis devised by the business minds of manufacturers on which they will be prepared to offer bids if proposals are issued by the Government. It is on the successful working out of this business arrangement that our hopes of speedy rearmament depend. I will point out the difficulties that encompass the subject, and you then can judge what encourage-

ment we have to hope for a supply of modern guns.

You are aware that the Gun Foundry Board decided that there should be no Government foundry. The share of the work of the Government was limited to that comprised in gun factories, one for the Army and one for the Navy, in which is done the finished-boring and turning, rifling, fitting breech apparatus, and assembling parts; all work of foundry proper, including casting, forging, rough-boring and turning and tempering was relegated to the private industries of the country. There is no question of the inability of any foundry in the United States to perform the work required. Mr. Sellers, of the Midvale Works, near Philadelphia, has succeeded in supplying some tubes for 6-inch guns, and the Cambria Works, at Johnstown, Pa., have undertaken to make some hoops, but this is all that can be achieved by their limited equipment. The limitation in the case of the Cambria Works applies only to its forging, boring and turning apparatus. It possesses furnace capacity for casting the largest ingots required for cannon. A manufacturer undertaking the work of supplying the material for all classes of guns must erect a suitable plant.

The cost of the plant is stated as follows, taken from the report of the Gun Foundry Board:

Casting	$250,000
Forging (hydraulic press)	150,000
Rough-boring and turning	210,000
Tempering	50,000
	660,000
Additional cost if liquid compression be adopted	175,000
	$835,000

The cost is based upon prices abroad; in round numbers the manufacturer must expect to invest one million dollars in a plant. He cannot expect to do this unless he is satisfied that it can be kept in operation for a certain time sufficient to remunerate him.

It is also necessary that the time during which the plant would be employed should be continuous, and this must be assured, for the purpose of avoiding the uncertainty attending annual appropriations which depend upon the will of each Congress to be continued or withheld. It thus becomes necessary that a lump sum should be secured for this purpose, which would stand for a guarantee for the execution of such contract as might be made. The question, then, was what sum of money was necessary to appropriate in order to secure the contractors, and assure a supply of ordnance for the Government.

The necessary outlay being so large, and the Government desiring only to treat with the most responsible parties, it seemed reasonable to suppose that those embarking in the work would be very few in number, probably but two establishments would take it up, one for the Army and one for the Navy. On this supposition the calculation was made on a unit of works, that is, to find the amount sufficient to induce one establishment to go into the business.

An output of 2,000 tons of forgings per year was taken as a basis for production. It was estimated that the average price of the steel would be twenty-five cents per pound, some more, some less; this gave $559 as the cost per ton of 2,240 pounds. At this price the cost of the yearly production of 2,000 tons would be $1,118,000. Allow, as a fair profit to the business, 15 per cent. of this amount, and we will have for yearly profit the sum of $167,700; and continuing this for six years and a half, the profits will amount to $1,090,050, a little more than the amount of the original outlay. The lump sum required to be appropriated for this purpose would be six and a half times the amount of the cost of the yearly production, or $7,367,000. This agrees with the report of the Gun Foundry Board, in which you will notice that the sum mentioned as necessary to be appropriated is $15,000,000, one-half for the Army, one-half for the Navy, that is $7,500,000 for each arm of the service, such amount being sufficient to secure the supply of material, at the same time assuring the contractor of a fair remuneration. This explains the figures given in the report of the Board.

I call your attention now to the wording of the proposals recommended to be issued for this work. "Said proposals shall divide the steel required into two lots. Each lot shall include all the parts for one-half of the number of guns for each caliber; each bid must include all of a lot or lots."

You see that, though the calculations for cost were made on the basis of a unit of works, there is nothing in the proposal favoring a monopoly in the work. Several manufacturers may bid, and the work be thus divided; this would result only in a more remote remuneration for their outlay. But the Board takes the precaution to require that in bidding for a lot or lots the contractor shall undertake to supply all the parts of the lot for which he bids; this ensures that his works shall be thoroughly equipped for the work he takes in hand. It would be a want of foresight to arrange the lots so that a few small establishments could bid for all the small parts, leaving only the heavy work to be done by those establishments who are willing to bear the expense of erecting a large plant. It is all important to the country as a means of National defence that these large plants should be erected, and all means should be taken by the Government to encourage the work; thus, by requiring all parts of the gun material to be included in a lot, an advantage is given to those establishments which propose to make their plants complete.

Supposing contracts to be made for the material, you may accept the period of delivery, stated in the Board's recommendations relative to proposals, as deserving of all confidence. It required that "Each bidder shall agree to deliver yearly a specified quantity of each caliber, the time of delivery of the smaller calibers to commence at the expiration of not more than eighteen months, and that of the largest calibers at the expiration of not more than three years from the date of the acceptance of the contract." This estimate is determined by positive information on the time necessary to duplicate the best tools now in use at the largest foundries abroad. The supply of the plants is an affair that would be entirely in the hands of the manufacturers themselves, who would naturally consult their own interests in equipping their establishments; it would be for them to choose between adopting tools of approved utility purchased abroad or encouraging home manufacture and risking failure by undertaking the work with the first productions of a new industry. There can be little doubt that, being bound by contract as to the time of delivery of the production of their works, they would wish to commence operations with tools of well-known capacity; the home manufacture would naturally follow, and would, no doubt, improve on the standard, but it would be a great risk at the inception of the manufacture to work with untried implements, The time for delivery of the productions of the foundries is predicated upon the supposition that the first tools used will be bought abroad, and upon the known capacity of such tools to turn out a certain amount of work in a given time. On any other basis the time of delivery would have to be indefinitely extended, in fact there would be no data on which to make a calculation. So much for the foundry work.

It is manifest that the delivery of the the tempered material for guns, roughbored and turned, is of no avail unless the gun factories are prepared to take the parts as they arrive, and to smooth-finish and assemble them. These indispensable establishments must be organized while the material is in course of manufacture.

The cost of a plant for a gun factory is given as follows by the Gun Foundry Board:

Guns up to 6-inch caliber.....	$50,000
" from 6-inch to 12-inch caliber...	150,000
" " 12-inch to 14-inch caliber..	350,000
Buildings and shrinking pit.....	350,000
	$900,000

"Three years will be required to complete the tools, construct the shops, and establish the plant."

This period is intended to represent the time necessary to complete the factory, equipped for the fabrication of cannon of all calibers up to the largest available for warfare. The building and the tools required for the smaller calibers, including those for 8-inch guns, could be prepared in less time. The building, for example, could be erected in one year, and the smaller tools could be delivered and put in place in a year and a half, which, you will notice, is precisely the period of time required for the commencement of the delivery of the material for the smaller guns. Thus the time for the delivery of the material and the time when the factory would be ready to receive it synchronize, and if the authority

to erect the factory be given at the same time as the contract for the manufacture of material the work will go on harmoniously from the commencement. It is evident that the two operations must be regarded as necessary parts of one transaction; one is of no practical use without the other. In the case of the gun factory, as in the case of the foundry, I have to state that the cost of tools is predicated on prices obtained abroad, and the time of their delivery on what is known as the period required for duplicating those in use in England, France and Russia.

I hope that the practical thoroughness of the report of the Gun Foundry Board is appreciated by the services. I make this remark before a naval meeting in order to point to our indebtedness to our brothers of the Army, with whom we share the credit of the work.

We thus see that, if during the approaching session of Congress, there should be enacted all the legislation necessary to equip the two arms of the service with modern ordnance, and if the steel manufacturers should respond to the proposals of the Government, it would not be before the early part of 1888 that we would be able to commence the fabrication of the smaller guns at the factories, and not until a year and a half after that that we would be ready to take in hand the guns of the largest caliber. It is very evident that, in comparing our chances of speedy acquirements of ships and guns, the ships are the more readily attainable. For their construction we have ship-yards whose plants can be readily supplemented with the additional tools that will be required; but for the fabrication of cannon we have yet to commence the erection of plants and to inaugurate the manufacture of the material. We have the satisfaction of knowing that, since the presentation to Congress of the report of the Gun Foundry Board, a committee has been appointed in both houses to take into consideration the capacity of the foundries in the United States to provide steel for ships and guns, as well as the capacity of our ship-yards to construct modern ships of war. This action on the part of Congress is a step in the desired direction, and if time be found during the session for the deliberate treatment of National subjects, we may expect that some definite method for advancement may be matured.

ARMOR.

Another sign of encouragement is to be found in the establishment of the "Fortifications Board," on which the Navy is well represented by two members of this Institute. There can be no doubt that this Board will recommend that one line of the coast defence shall consist of armored turreted or barbette vessels, the construction of which would call for a large supply of armor plates. Here we see another powerful reason for the establishment of foundry plants.

If it shall be decided to commence the construction of armored vessels, and to face forts with armored plates, it will be necessary for the Government to make a definite selection between the steel plate and the plate of compound armor. The compound armor, again, is not all of one patent. The Cammel plate, consisting of a previously prepared iron plate on which the steel facing is cast, is all prepared in the rolling mill; the iron plate is rolled to dimensions, and, after the steel facing is placed, it is finished by passing through the rolls. With the Brown compound armor plate, however, the iron plate is prepared as before, but the steel plate for facing is also prepared separately, and this is forged under a hammer. The steel plate being then placed on the iron plate, separated from it by distance pieces, melted steel is poured into the space between the plates, thus welding the one to the other; it is finished by being pressed through the rolls. In this case we find a necessity for the heavy forging hammer or press. The steel plate, as manufactured by Mr. Schneider, at Le Creuzot, is worked entirely under the hammer, is tempered and subjected to other treatment. My own judgment favors the steel plate. I think it more in the course of advanced ideas, and I am content with the results it has achieved in experiments; and the more experience we have in the manufacture, the more will we approach perfection in results. If the steel plate be adopted by the Government, we see how indispensable it is for us to be provided with large forging facilities, whether with the hammer or forging press.

I am aware that at Terre Noire, in

France, it is claimed that a good steel armor plate can be cast which needs no forging, and I am under the impression that the same idea obtains at one of our own large steel establishments, but I have no confidence in such material, and I think that the first shot from a modern gun would dispel the illusion of those who entertain the idea. I accept as a fact that for the manufacture of steel armor plates there is required a heavy forging plant, and if we possess such facilities for forging our ingots for cannon we have secured apparatus that will be equally serviceable for treating armor plates.

An approximate calculation will give an idea of the amount of material that would be required for the purpose of the Navy. Supposing that the United States should undertake the rapid construction of an effective ironclad fleet, including armored cruisers and vessels for coast defence, the largest probable rate of construction would not exceed the completion of one armored vessel of 7,000 tons displacement, and two of 5,000 tons each year. This would require a total annual expenditure of seven and a quarter millions of dollars, and an annual supply of armor of about 3,800 tons, including their armor for protective decks and protecting shields for light secondary batteries.

During the first year after the construction is commenced, not more than half this amount of money above estimated would be expended, nor half the armor required. This approximate estimate is made supposing that the amount of armor now carried by modern vessels will continue to be used. In addition to the above supply of armor for new ships, the completion of the double-turreted monitors now on hand would require an immediate supply of 3,000 tons.

Nor must we forget the amount of material that would be required to *arm* the ships that I have proposed. There will be required for the batteries of the seventy unarmored cruisers, the ten armored cruisers, and the twenty-five coast defence vessels about 7,000 tons of *guns*, which we may roughly estimate at about 10,000 tons of forgings.

I give these estimates to illustrate the high figure to which the wants of the Navy swell. It is well that we familiarize ourselves with the idea of large masses of material and large expenditures of money; the rehabilitation of the Navy is a work of magnitude, and Congress and the people must be approached without disguise. The steel manufacturers may also recognize their opportunity, and find that their interests lie in supporting our efforts.

TORPEDOES.

Everything relating to torpedoes is legitimate work for the Navy, and merits the close attention of this Institute. Although the stationary mine for the defence of the coast is relegated to the Army, yet it is a weapon which we may, either at home or abroad, be called upon to manipulate, and our instruction in it is very thorough at the torpedo station at Newport; but the movable torpedo is the one that more especially demands study and development from us. In seeking for indications of advancement in this field, the difficulties that surround it are impressed upon us by the paucity of the results. The essential requirements are perfect control of direction both vertically and laterally. The Whitehead torpedo is the only one that possesses these attributes sufficiently pronounced to justify its being issued as a war implement. The control of the movements of the torpedo is effected by means of two rudders, the one vertical, controlling the horizontal deviation, which must be permanently set at such an angle as experiments with each torpedo show is necessary to make it go straight; the other horizontal, regulating the immersion, which is actuated by a piston under air-pressure governed by the hydrostatic pressure of the surrounding water. The principle on which the latter result is achieved is recognized, but the device itself is only known to the experts of those nations who have paid the price demanded for the information, and its nice adjustment is the result of multitudes of experiments, and the expenditure of large sums of money. The results seem to be very satisfactory, but the control over the lateral deviation of the Whitehead torpedo does not meet all the circumstances of service. I believe I am correct in stating that no confidence can be placed in the operation of it when discharged from the broadside of a vessel moving through the water. When fired

ahead or astern the direction is sustained as originated, but its course is very erratic when projected under other conditions.

In this respect the torpedo of Captain Howell, of the U. S. Navy, is much the better equipped, for the power being stored in a fly-wheel revolving in a longitudinal vertical plane, its gyroscopic tendency makes it impossible for the torpedo to deviate from its original course in a horizontal plane. His device for regulating immersion is not yet sufficiently perfected to ensure the required action with certainty. This can only be done by repeated experiments, which must extend over considerable time, and involve the expenditure of much money. Thus far the Government has expended but a few hundred dollars to assist the development of this torpedo, but as its good points are the more appreciated, the chance increases of securing liberal aid for experiments. We have good expert opinion for the belief that the Howell torpedo is the successful rival of the Whitehead.

But it is important to note the effects that have been produced by the introduc tion of the Whitehead torpedo. It has introduced an element into the calculations of war that interfere materially with the conclusions that had been reached on the equipment of ships.

The introduction of the weapon involved that of means to utilize it, and some ships were fitted with tubes from which it could be projected. The next step was the construction of very fast torpedo boats, assigned to ships capable of stowing them, which were expected to be launched at sea to assist in a naval action. The general adoption of this idea has led to the construction of larger vessels having increased speed, which, apart from the destruction they are expected to work by their torpedo attack on large vessels, are designed to act as torpedo boat catchers, and, in addition to their torpedo battery, are fitted for this purpose with a formidable supply of rapid-firing single-shot Hotchkiss and revolving cannon capable of perforating all parts of a torpedo boat.

The French style this type of vessel a "dispatch torpedo boat," and they are represented by the first one of the class called La Bombe, which was launched in August last at Havre. Eight vessels similar to La Bombe are now included in the official list. These vessels measure about 196 feet in length, with a draught of water of about six feet, on a displacement of 360 tons. They are built entirely of steel, and care has been taken to make the hull as light as possible, and at the same time strong enough for the navigation of the high seas. They develop about 1,800 horse-power of engines, attaining a speed of nearly 18 knots. They have three masts, and are provided with the latest improvements for handling torpedoes, and with apparatus for electric lighting, etc. Hotchkiss single-shot and revolving cannon form the gun battery. The tubes for the Whitehead torpedo are above water on each bow, parallel with the keel.

The British Admiralty have prepared designs for this new class of vessels called "torpedo gunboat," and in October last issued proposals for their construction to leading shipbuilders in England. These vessels measure about 200 feet in length, while their displacement with a mean draught of about 8 feet will be 450 tons. They are to be built throughout of steel, the decks covered with wood planking. They will have four torpedo-launching tubes, one forward, one aft, and one on each broadside. Their gun armament will include a breech-loading 4-in. gun, and four three-pounder (47 millimeter) rapid-firing guns in addition to the machine-gun armament which it is now usual to supply to torpedo boats. They will be provided with twin screw engines of a total horse-power of about 2,700, and the speed expected is from 18½ to 19½ knots. They will have a protective deck of about three-quarters of an inch in thickness, with a protection of coal of about three feet thick around the boilers and machinery.

We see from this what are the constituents of a modern fleet. The armored ships form the line of battle-ships; these are attended by tenders and dispatch boats and by the torpedo boats, which they launch before going into action, and to these are added the torpedo boat catchers, whose province it is to destroy the torpedo boats of the enemy with their guns, as well as to operate as occasion may serve with torpedoes against their battle ships. All of this formid

able array of boats and small vessels is now considered necessary for the protection of the battle ships against the spar and Whitehead torpedoes.

Admiral Hobart Pacha, who commanded the Turkish fleet during the Turco-Russian war, gives his experience on this subject, and he considers that the power of the torpedo as a weapon of offence, as well as of defence, is enormously exaggerated. He does not deny the deadly effect of the weapon itself, but he rates the difficulties of successfully applying it very high, and with vessels at anchor he shows most effectively how the attack can be guarded against even with improvised means at the disposal of any well-equipped vessel of war. He anchored his ships in groups of four. These were surrounded by the boats of the vessels, twenty-four in number, which were anchored in a circle, and connected together by a wire rope which is buoyed half way between the boats. The boats are estimated at nine yards in length, the twenty-four spaces between the boats are fifty-four yards each, the radius of the circle described by the boats is five hundred and fifty yards, which keeps them four hundred yards from the ships. The wire rope is suposed to be immersed two feet in the water.

The object of the rope is to catch the screw of any attacking torpedo boat. The Admiral states that "it has been proved that common rope, used for want of anything better, has effectually checked the career and capsized an attacking torpedo boat in her attempt to destroy a Turkish ship in the Black Sea during the last war; and I know that most satisfactory experiments with the wire rope have been made elsewhere. The result of these experiments was that a torpedo boat, steaming nineteen miles an hour, has capsized while dashing full speed on to an imaginary enemy's ship." An instance is also cited in actual practice where a most gallant and dashing attack made with a spar torpedo was frustrated by this system of guard.

In Admiral Hobart's article he incidentally contributes most important testimony to the ease with which the Whitehead torpedo can be made to deviate laterally from its course. He says: "One of these torpedoes struck the chain of the flag ship and went on shore unexploded; another struck on the armored belt of a corvette and exploded, but, the blow *being at an angle*, it did no material injury." If we apply this evidence to the comparative directive power of the Whitehead and the Howell torpedo before referred to, we will see that in the two cases cited, where for want of directive power the Whitehead torpedo failed to accomplish any result, the Howell torpedo, possessing this property to an eminent degree, would have resisted the effort to deflect it, and would have achieved its object. This strikes me as very conclusive that it is a necessary requisite for an automatic movable torpedo to have inherent in it a positive directive force, so as to resist efforts calculated to cause deviation. The want of this is a defect which we find in the Whitehead, but we have it in the Howell torpedo as its most essential characteristic. I take much interest in the experiments with the Howell torpedo, and I hope the Government will carry them on on a liberal scale. I have faith in its success.

What has been stated is sufficient to show that there are two sides to the torpedo question, or rather, that the power of attack with the weapon is so much neutralised by means available for defence as to deprive it of the prestige it had acquired before means of defence were inaugurated. In shallow waters or in harbors where stationary mines can be planted or floated at convenient depth of water, they are a sure means of destruction, but with net protection, cordons of boats, secondary batteries and a bright lookout the evidence goes to show that to the present time the effect in offence has been very trifling in result. The great expense, however, of the present battle ships makes it necessary to guard against all chances of service, and thus we see that the nations having the most at stake in this matter consider it necessary to protect their fleets with supplementary squadrons of torpedo boats and again with torpedo-boat catchers. Thus far the matter rests much in the realm of theory; it remains for the realities of war to solve many of the questions which are now matters of opinion and discussion.

It will be noticed that in stating the constituents of a modern fleet, no mention is made of the ram. This class of

vessel, built with sole purpose of operating the ram unsupported by other weapons, was considered some years ago as a suitable vessel to accompany the battleships and to take advantage of the melée to ram the enemy, but advancement in the development of this idea has ceased since the adoption of the torpedo boat. At present we find in the English Navy vessels either turret rams, as the Conqueror and Hero, carrying heavy guns in a single turret, or torpedo rams, as the Polyphemus, with complete facilities for ejecting the torpedoes, and armed with rapid-firing cannon and machine guns for defensive purposes, but no vessel intended to operate solely with the ram. It seems to be conceded that all the useful purposes of a ram can be performed by the fighting vessels themselves, all of which have a powerful permanent ram bow stoutly supported by the horizontal armor deck or armor belt. The first Advisory Board recommended that rams should form a part of our fleet, and the present Advisory Board has submitted the general features for one, but it was found necessary to give the vessel a displacement of 3,000 tons so as to ensure a draught of water sufficient to enable the ram to operate below the armor belt of an armored vessel.

In referring to the armaments of the numerous classes of vessels which now form a modern fleet, we find that there are none that do not have a number of machine-revolving and rapid-firing single-shot guns as a portion of the battery. So general is this application, that every ship carrying large guns now has two batteries, and in speaking of them they are indicated as the primary and secondary batteries. No modern cruiser or armored vessel would be complete without this secondary battery. They are considered necessary in general action for clearing open decks, for entrance through portholes, and, as their penetration is very satisfactory at long distances, for the damage they can do after perforating the sides of unarmored vessels; they are also handy guns for use in tops, and are indispensable for protection against boat attacks by boarding and by torpedoes. This aid to the primary battery is regarded as an established provision for a modern battle ship.

Accepting the correctness of this conclusion as applied to ships armed with modern artillery, how much more does it apply to ships armed with guns which are not fitted to answer the demands of modern warfare?

I was particularly impressed with this conviction during a late visit on inspection duty to the U. S. S. Brooklyn, just fitted for sea. I found the old historic ship in good order, well officered, and with a young and hearty crew. Although she had been but five days from the navy-yard her organization was complete, and drills were already commenced; but as I stood on her poop deck and looked down on a fine body of men at their quarters, standing by their 9-inch smooth-bore guns, my mind instinctively jumped to the contemplation of action, and I pictured to myself the scene if engaged with an enemy armed with modern artillery, and with speed that would prevent the Brooklyn coming to close quarters, the only position in which her battery could be effective. I could recognize no hope in such a contest. The Brooklyn has, besides her smooth-bore 8-in. guns, one 8-in, converted rifle, one 60-pounder rifle, and four 37-millimeter Hotchkiss revolving cannon. The first two guns would be moderately effective at long range, but the 37-millimeter guns are only of use to guard the sides of the ship against torpedo-boat attack. I felt that here, if anywhere, and more than anywhere else, was a need for the largest rapid-firing single-shot guns. The 57-millimeter Hotchkiss gun, throwing a shell of six pounds weight, with a sufficient bursting charge, could be used to great advantage; its penetration at 1,000 yards is sufficient to penetrate two inches of iron, and it would, without doubt, perforate the side of any unarmored vessel, and it would give encouragement to the men to feel that there were some means in their power by which they could give back the blows they were receiving.

While we remain in our present helpless condition in respect to our primary batteries, I think that a great effort should be made to increase the power of our secondary batteries; our ships should be supplied with as many of the 57-millimeter Hotchkiss single-shot guns as can be accommodated, the 47-millimeter guns should be put in the tops. This gun can also be utilized as a boat

gun for cutters that are now provided with no boat armament. The 37-millimeter revolving Hotchkiss cannon is undoubtedly the gun most efficient for repelling boat and torpedo attacks, and the Gatling gun is indispensable for use on shore with landing parties, but for the secondary batteries of ships for purposes of general action, and for the protection and encouragement of men stationed at our smooth-bore guns, we should place in position as many of the largest sized single-shot rapid-firing Hotchkiss guns as can be accommodated.

This involves, I well know, the question of stowage, for the amount of ammunition for these guns must be liberal. Imaginary established rights to space and store rooms will have to yield to the necessity of the chief want, and much that is now considered necessary in other departments may be found to be superfluous. Fortunately, in our old-fashioned ships the aggregate of the space for stowage is ample, and a judicious curtailing of space occupied by other departments will, without doubt, result in accommodating to ammunition required to make the secondary battery effective.

STEAM ENGINEERING.

Equally important with ships and guns are all matters pertaining to steam engineering. Fortunately our coast trade and the navigation of our inland waters has saved us from being unable to build engines and boilers, and in this respect we may feel that we are equipped to such a point as will make only supplementary such improvements as may be found necessary when the reconstruction of the Navy shall assume an earnest character, on this subject, however, I shall allude, with deference, to two matters which I consider well worthy the thought and attention of those charged with the important duty of designing and building our engines and boilers. One is the weight of our engines, the other is the necessity of a new type of steam generators.

In determining the general features of a vessel of war of a given displacement, the first question is as to the weight of the boilers and engines. If a certain speed is required, and the engineer declares that a certain weight of engines and boilers is necessary to produce it, it must be yielded to him, as he is responsible for the horse-power to be developed. The constructor, ordnance and equipment officers must do the best they can with what is left of the displacement. I do not think that sufficient attention has been paid to reducing the weights of our engines. I am the more confirmed in this opinion by the comparison of the weights of engines in ships lately built abroad with those assigned to our vessels of similar displacement.

I am aware that it has been the habit of some engineer officers to read these statements with reserve, to accept them with certain grains of allowance; as, for example, it is said that many things which are entered in the sum of weights with us are not so entered abroad, such as fire-room floors, platforms, ladders, spare parts, etc., all the appurtenances. It is said that the published weights comprise nothing but the actual engines and boilers themselves. I have never investigated the basis on which these reports are made, consequently am in no position to allow or to disprove this assertion, but my mind has never been satisfied that the reason was satisfactory. It seems to me more natural to take the reports as expressing what they purport to do. I believe that by careful study of this detail we can reduce weights; no one will deny that we can reduce w g its very much by substituting steel for iron in many parts of our engines, as the superior strength of the steel will allow of very much reduced dimensions.

But how much more can these weights be reduced if a multitubulous boiler be adopted as the steam generator? We are now brought face to face with a positive demand for great speeds; ordinary speeds will not satisfy the demands of the times.

This can only be produced by increased power developed at the screw, which means an increased supply of steam to the engines. With the Scotch boiler, this means a multiplication of the number of boilers in order to obtain the increased grate surface, and a consequent large increase in the weight of the boilers and water to be carried.

At present, in order to avoid the necessity of carrying so much weight, only made necessary at the highest speeds, abnormal means, as forced draught, have

to be resorted to. The fire room is closed. The blowers worked with great violence, and the furnace, combustion chamber, up-take and smoke-pipe are converted into parts of a blast furnace, the effect of which is to burn up and destroy rapidly all parts that are not surrounded by water. It seems to me that when we have reached the point where it is necessary to destroy the boiler in order to obtain the power demanded, it is time to look for a new steam generator. I am presenting no new idea, but I wish to emphasize the necessity of this effort, and to suggest to this Institute and to the Navy, the necessity of action in this matter.

The two more familiar types of multitubulous boilers for sea-going vessels are the Herreshoff and the Belleville boilers. I hazard no description of them; they are familiar to you. They have been going through a state of probation for several years. Mr. Herreshoff has increased the size of his boats which carry this boiler, until he has a vessel of 94 ft. in length, 11 ft. beam, 28 tons displacement, 4½ ft. draught aft, and 3 ft. forward, with which he has obtained a speed of 21 knots per hour. The French Government has experimented with the Belleville boiler, and the performance of the dispatch boat Voltigeur, recounted in a paper published by this Institute in 1883, is well worth attention, for it conveys undeniable testimony of the success of the experiment; and, in fact, the trial in May last, of the French dispatch boat Milan, of 1,560 tons displacement, 303 ft. in length, and 33 ft. beam, takes the matter out of the region of experiment, and exhibits the Belleville boiler as an accomplished success. This vessel, on a draught of water of 12 ft., has attained a speed of 18.4 knots, with a developed horse-power of 4,000.

The Herreshoff and the Belleville are the only tubulous boilers that I know of that have as yet been applied to sea purposes, but we have the Babcock and Wilcox, and the Moore boilers of the same general character and type which are in use for stationary purposes, for heating or for working stationary engines, and no doubt these can be successfully applied to sea purposes by introducing modifications that would be found necessary in the new sphere of usefulness.

I will not attempt to institute comparisons, nor to discuss the details nor proportions of various types of boilers, but wish to emphasize the importance of a careful examination of a subject which promises to produce a safe and desirable marine boiler, with a reduction of weight of 30 to 50 per cent. over the Scotch type, thus adding enormously to the total efficiency of a ship.

The designing of a small gunboat is now under consideration at the Navy Department. Her displacement is fixed at 800 tons. If the same conditions obtain as in the cases of proportional weight cited above, nearly one-sixth of this will be devoted to providing for the weights of her boilers and engines, and a tenth to the accommodation of coal, thus appropriating about one-fourth of the entire displacement. This is probably the best that can be done with the present type of boiler. The ever-increasing demand for storage for ordnance supplies, consequent upon the large charges of powder now used, and the space needed for the stowage of ammunition for the secondary batteries, has reduced the equipment outfit to a minimum, has contracted the dimensions of the hold so that provisions can only be carried for a limited period, and seriously curtails the living spaces for the crew. A lightening of weights must be brought about in every department, and special efforts should be made in those appertaining to the engines and boilers. If the law authorizing the new vessels did not preclude anything in the nature of an experiment, I don't hesitate to say that I would like to see the first experiment in this direction made on this new gunboat; if the result were to be a total failure, I should consider it cheap experience. And it is well to mention just here another advantage attending these multitubulous boilers—that there is no trouble in removing them, as they are arranged in sections which can be renewed without tearing the ship to pieces by taking up decks. This concludes what I have to say on this subject. It may be that I underestimate some of the difficulties which I know exist in making this new departure, but in consideration of the advantages that will ensue from a successful application of

this steam generator, I think they are worth the effort.

HYDROGRAPHIC OFFICE.

After touching on subjects on which our Navy is deficient, it is a relief to turn to one branch of the service where our advance is not only creditable, but promises to equal, if not to surpass, the development of similar work in foreign Governments. I allude to the Hydrographic Office.

A large number of officers are connected with this office, but the work is of such a character that it does not force itself so much on the attention of the service as do other branches. Its primary work is to supply our ships with charts and to carry on original surveys out of the waters of the United States; but the duties to effect this are multifarious, and a very perfect organization is necessary in order to guard against errors or oversights, which might produce very serious results. This office must be sure that, in distributing charts and sailing directions, it has the latest and most trustworthy information; accuracy is indispensable in the charts by which a ship is navigated. It is customary to place implicit confidence in a chart, unless warned of inaccuracies, and the responsibility of accident falls on the Hydrographic Office if reasonable precautions have been taken by the ship. It is thus very important to be able to trace error to its source, and in the organization of this office every precaution is taken to ensure this personal responsibility. It is impossible to assert that no error can occur in any system, however perfect it may seem to be, and however faithfully the agents may work; but where a system is so arranged that an error is sure to be traced back to the person responsible there is no doubt that a special guard against inaccuracies has been secured. The checks that are introduced in this respect in the Hydrographic Office secure this personal responsibility, and it must inspire much confidence in the work of the office.

The office is in correspondence with all similar institutions in the world, also with our ships of war and the United States consuls in the seaboard countries, and no chart is issued until all known charts of the region have been consulted, and all information has been collected from every available source.

At present the larger portion of charts issued to the Navy are purchased abroad, the British Admiralty charts being in the largest proportion. In fact, the Navy is practically dependent now on Admiralty charts, which form 85 per cent. of the chart outfit of a cruiser on the European station, 76 per cent. on the Asiatic, 30 per cent. on the Pacific, 40 per cent. on the South Atlantic, and even 25 per cent. on the North Atlantic station. Corrections are being constantly made and new charts purchased, but the ultimate object of the Hydrographic Office must be to make itself independent of foreign purchases, and equip itself with its own original plates of all the waters of the world. We have only to imagine a state of war to recognize at once the necessity of thus providing ourselves. Of course, the plates must be electrotyped for printing purposes, all of which requires time and money. This necessity is recognized by the present accomplished and energetic hydrographer of the Navy, and small sums each year are devoted to this purpose as they can be spared from current expenses, but the work should be separately provided for as a distinct object, and appropriations made accordingly. It must be remembered that this need exists not only for the Navy, but for the merchant marine, which is forced to purchase its foreign charts of dealers, who naturally sell to them charts of old date as long as any of the old stock is on hand.

The number of the original plates now in the possession of the Hydrographic Office is about 350, and quite a number of them are electrotyped, but when we consider that the number of charts required for navigating all the waters of the world now reaches over 3,000, we see that there is much labor yet in store for the office before we can be considered independent in this matter. All other nations of any importance are entirely independent in this respect, and the thorough organization that now obtains in our office justifies this consideration for it.

All other details appertaining to such an institution are carefully worked out. Sailing directions always corrected to date and notices to mariners are issued with dispatch, and our consuls abroad

are kept informed of all that transpires necessary to be communicated to our merchantmen abroad.

One of the best proofs of the practical value of the Hydrographic Office is the favor with which it is regarded by our merchants and merchant captains. The establishment in our principal seaports of branch offices has had much to do in calling its usefulness into notice. It is found now that ship captains bring their charts to these offices for verification and correction, and many are surprised to find that new editions of their charts showing quite different hydrographic conditions have long since supplanted those which they were using. The notices to mariners, also, which give immediate notice of newly-discovered dangers, are thus more rapidly communicated to those who are the most interested in them. The interests of ship captains, thus aroused, works now to the advantage of the office itself, for it is in constant receipt of information communicated by those who have been benefited by its operations. The sale of the hydrographic charts has also increased to a great extent.

A striking feature in the work of this office is the monthly issue of the pilot chart of the North Atlantic Ocean, which presents graphically any information relating to the North Atlantic of interest and value to mariners. There appears on the chart a statement of the information collected during the month preceding, and a forecast of what may be expected during the month following. This chart is carried by all Trans-Atlantic steamers, and many of them are sailed in accordance with its instructions. The prevailing winds, the position of icebergs and that of wrecks along this highway of the ocean are items of knowledge much needed by the navigator, and it is expected that the observations now being collected will enable the office, in a short time, to lay down a very close approximate limit of fogs during the different seasons of the year which will be a valuable addition to the present guards against accidents.

We can congratulate ourselves on the creditable and most useful work that is being done by this branch of the Navy Department, and it is to be hoped that our present able hydrographer may be encouraged in his work by liberal appropriations to enable him to make the Government independent of foreign aid in the supply of charts.

I have finished the work that I set myself to perform. With the exception of the Hydrographic Office, which I recognize as established on a sound basis and only needing appropriations of money to make it independent of foreign aid, the subjects on which I have touched are those in which we are most deficient. I have confined myself to them as being the essential ones to be borne in mind as needing attention in the work of rehabilitation. The main object of my address is to preach encouragement to those who are left to occupy the field of action. The chance for speedy restoration to the position that the Navy once occupied is not cheering at present, but we have cause for encouragement in the fact that the first steps have been taken, and it is the first step that always costs the most effort. We have the right to recognize that the advance has commenced, and it is the duty of every individual member of the service to prepare to do his share in aiding the movement.

As I said before, notwithstanding the decadence of the *materiel* of the Navy, we have reason to be proud of the condition of its personnel, and we feel confident that it embodies talent capable of treating the many questions of science and practice that are to be encountered. These involve much work, and demand thorough knowledge of the subjects to be treated, and I am tempted to emphasize the source from which the Navy, at this time of trial and exacting requirement, draws the strength which enables it to respond to the call made upon it. The source of power is in the Naval Academy, which has saved the Navy. The portion of knowledge there acquired has expanded the minds of its graduates, and their habits of study have enabled them to go on and better their instruction. The result has been the wide dissemination in the service of advanced ideas which keep pace with progress and fit the officers for the work they are called upon to perform.

I have the honor of being the senior graduate from the Naval School at Annapolis, but I did not enjoy the advantage of the academic course, which

came after my time. I claim it, however, as my Alma Mater, and I take as much pride in it as do those of younger classes; and, in concluding my remarks, I would say to all graduates that, while we cling with affectionate memory to the associations that surround the Academy, and while we love to share with it the credit that its graduates have achieved, we should not forget him to whom we owe the gift, we should ever keep green the memory of its founder. It was the Honorable George Bancroft who, when charged in 1845 with the care of the naval branch of the service, looked ahead into the future, and foreseeing the march of progress, and well appreciating the needs of *education*, conferred upon the Navy that ineffable boon, the full advantage of which we now reap. This revered sage still goes out and in among us, loaded with years and honors that a grateful people has bestowed, and occupying his time in still further adding to his enviable reputation in the present, and rearing a literary monument which will preserve his memory to posterity; but no class of his countrymen have so much cause to respect and honor him, or have so strong a reason for gratitude to him as have the officers of the Navy.

THE NAVY QUESTION.

By LIEUTENANT BRADLEY A. FISKE, United States Navy.

Written for VAN NOSTRAND'S MAGAZINE.

THE people of the United States are better fitted to build a modern Navy than any other people in the world. They are inventive, constructive, executive, persevering, enterprising and rich. The same circumstances which have produced Morse, Dahlgren, Ericcson and Edison; the same characteristics which have placed them ahead of all other nations in applying science to practical affairs and in pushing through great enterprises, would enable them to build a Navy of a higher type than any the world has yet seen.

A Navy at the present day is an organization comprising floating fighting machines of various kinds, and a number of men capable of handling them; and it is clear that ships, guns and torpedoes, together with the apparatus by which they are controlled, are in reality machines or tools adapted to special work, but constructed and operated on the same principles as govern all machines, tools, engines and structures.

So, the modern Naval profession has become a branch of the broad science of Engineering, advancing as that science advances, and contributing in turn to the progress of Engineering by each invention made and principle discovered in Naval science; for, since the principles of mechanics, mathematics, physics and chemistry underlie all branches of engineering, a step in one branch affects all the other branches.

The happy result attending the close relationship which has thus sprung up between naval science and engineering, is clearly to place the Navy more within the sympathies of the people; for since engineering, including civil engineering, steam engineering, sanitary engineering, mining engineering, electric engineering, metallurgy, chemistry, &c., is very closely identified with the interests of the people, the interests of the Navy are clearly becoming closely identified with the interests of the people, even in time of peace.

Now, the idea that the interests of the Navy can be in accord with the interests of the people, in time of peace, is not generally held; and a prominent paper went so far, a few days since, as to say that the interests of the Navy were opposed to the interests of the people. While, too, the maintenance of a small but efficient Navy is approved by most men, it is nevertheless considered a disagreeable necessity, and one entailing an enormous expense, allowable only because it may save a greater expense in time of war; and as most people have read Marryat, the Naval man appears to their imagina-

tion as a man apart from other men, full of strange sea-slang, horribly profane, chewing tobacco, bow-legged and usually drunk.

A very brief consideration, will show, it is believed, that the interests of the Navy are closely allied to the interests of the people, instead of opposed to them; so that the building of a suitable Navy would not benefit the Navy alone, but the people also.

The work of the Navy in aiding navigation along the coast and on the high seas, and in publishing books and charts for mariners, need not be mentioned, for this is well understood; but the good which would be done in the interior of the country by constructing a suitable Navy is not generally understood.

Perhaps the most direct good done would be the stimulation of the iron industry, and the unquestioned improvement which would follow in the manufacture of steel. The construction of a number of ships sufficient to act as an insurance on our property near the coasts, would benefit, not only the men engaged in the actual building of the ships, but also the men engaged in the mines, in the transportation of the ore from the mines, in the reduction of the ore in blast furnaces, in the making of steel, in the forging of large masses of steel, and in the fabrication of these masses into engines, armor plates, guns, gun-carriages, &c.

And the ordering of large forgings of the finest steel by the Navy Department, would justify capitalists in making the most elaborate and costly experiments looking to improvements in the quality of steel, to a cheapening of the methods of its production, and to a solution of certain problems as to the nature of steel, which would enable them to turn out steel of any desired combination of physical characteristics, such as tensile strength, elastic strength, elongation, &c., with unfailing precision. The necessary hammers and presses also which capitalists would erect, to furnish the navy with large forgings, would enable them to produce large masses of steel for other purposes, such as the building of machinery and of large structures throughout the country.

But we must not suppose that it would be only by the direct means of the employment of hundreds of thousands of men and the improvement in steel-making that the prosperity of the Navy would increase the prosperity of the country, for we must not forget that, by reason of the close relation now borne by Naval science to engineering and to the scientific work of the country, any improvement in ships, guns, engines and apparatus is at once felt all over the land.

Take the science of steam engineering, for example. No one can hold that improvements, inventions and discoveries in this science do not benefit the whole country, for steam engines are used everywhere, their use is daily increasing, and the principles underlying the construction and operation of all steam engines and boilers are the same, no matter to what special purpose any special kind of engine or boiler may be applied. Now, many of the most important improvements in engines and boilers have been brought about by the requirements of war ships, but the fact of an improved type of engine or boiler having been first used in a war ship has not prevented that improved type of engine or boiler from being used in merchant ships afterwards. A few years ago a steam pressure of thirty pounds per square inch was thought enormous, but now there are torpedo boats abroad which are run with 150 lbs. pressure, with proportionate increase of horse-power per pound of coal; and multitubular boilers have been made to work at a pressure of 500 lbs., expending only a little more than a pound of coal per horse-power per hour. It seems a very short time ago also that compound engines were first tried, in which the steam after doing its work in one cylinder in forcing the piston to one end of its stroke, was exhausted into another cylinder, and did similar work there at a lower pressure—and now we hear of engines in which the steam is made to expand in four cylinders in succession before it is allowed to exhaust into the condenser.

In every country, let it be borne in mind, in which great progress has been made in steam engineering, a very large part of the incentive has been the inducement held out by the Government to builders of the best engines for war ships; and the reason that the United States has dropped so far behind Eng-

land and France in engine building is simply that the Royal Navy and the French Navy have advanced and the United States Navy has not.

The struggling science of electric lighting also has been aided largely by Naval patronage, for in Europe and to some extent in this country, electric companies have received much substantial encouragement in the shape of orders for lighting war ships; and the tests of dynamos and incandescent lamps upon which the most reliance is placed all over the world, are those undertaken for the Franklin Institute by a Committee which consisted for the most part of Navy and Army officers whose chairman was a young officer in our Navy.

Certainly it will not take much consideration to show us that in the matter of ship construction, too, the interests of the Navy and the people are identical, for we can see at once that the plant needed for building steel war ships and the experience gained in building them would enable shipbuilders to improve and to cheapen the construction of steel merchant ships and even of boats. A comparatively small reduction in the price of steel plates would permit the construction of steel ships and boats at about the present price of wooden ships and boats. Steel schooners for instance could be built instead of wooden ones, and besides being more durable and strong, they would cost less for repairs.

Even in the line of explosives we can see that the requirements of modern warfare have contributed to the march of civilization and to the comfort and happiness of mankind, for the most reliable experiments made with explosives have been made with a view to developing weapons of destruction; and yet the conclusions reached and the improvements made have put means in the grasp of the engineer, the miner and the pioneer for blasting through solid rock with speed and safety.

That a close sympathy exists between the Naval profession and other branches of engineering is shown by the very numerous applications to warfare that are made of new discoveries, and by the fact that the sciences of steam engineering, shipbuilding, ordnance, &c, keep pace with the rapid advance of kindred sciences. New developments are constantly appearing. In steam engineering the rapid increase in the pressure at which steam is carried, in the quantity of coal burned per square foot of grate surface, rendered possible by the increasing use of the forced draught, coupled with great decrease in the weight of engines and boilers—all show that we are approaching speeds in ocean steamers that were undreamed of a few years ago. The progress going on in ordnance is more rapid still: ranges are increasing fast, and projectiles are growing rapidly in weight, and as yet we can see no limit, either to range or to weight of projectile. The science of ordnance is evidently in its infancy, especially in the matters of projecting large masses of high explosives through the air, and in swiftly and accurately propelling anto-mobile torpedoes under water. The application of electricity to ordnance is just beginning to throw its shadow before; for though we see it now used for firing guns and torpedoes, and for steering and propelling torpedoes at a distance, it is evident that it will soon have a larger field and be used for pointing great guns with speed and precision, and for communicating between vessels at sea without wires. The machine gun already fires 1,000 bullets per minute; the revolving cannon fires with good aim twenty shell per minute, each shell weighing about four pounds, and the light rapid fire gun fires fifteen shell per minute with good aim, each shell weighing six pounds and capable of piercing four inches of iron. All of these guns operate by hand, and are nearly automatic; but the Maxim gun introduced into England is absolutely automatic, the recoil of one shot furnishing the energy for loading and firing the next, &c. The problem of swiftly turning steamers is being rapidly worked out, some torpedo boats abroad being now able to turn within their own length. And we have just heard of a new explosive that promises to surpass nitroglycerine.

But this rapid improvement in all branches of Naval science cannot continue without continued study and experiment. Now that Congress has decided that we ought to have an efficient Navy, let us hope that Congress and the country will not suppose that progress has come to a stand-still, and that we must stick fast to what has thus far been done abroad; for

progress is marching with rapid steps, and the natural inventiveness of Americans will give us a great superiority over all other nations, if we only profit by it.

The reverse plan has, however, been followed in this country for the past twenty years, and many American inventors after having been discouraged or ignored by their own Government, have gone to Europe and received substantial encouragement, so that many of the best systems in use to-day by foreign powers are the invention of American citizens. Clearly, "these things ought not so to be."

If we are content to follow where our natural genius shows that we should lead, we may attain certain results at a less cost of money than if we undertook experiments ourselves; but we shall always keep about two years behind other powers, so that in case of war we shall find ourselves at a proportionate disadvantage; and, besides, we shall never rise to so high an excellence as we should by properly encouraging American inventors to turn their thoughts to means for protecting their own country. Moreover, the inducements held out by the Government to inventors would operate not only to give the Navy improved apparatus and machinery, but would also stimulate study of practical science all over the country and tend to enhance our material prosperity.

In case, however, we do not attempt progress, but stick fast to what has been done in England, refusing to spend money in experiments and fearing to make mistakes, so that our ships, guns and engines will be virtually English, and in case one of these ships meets an English ship and whips her, let us not forget to give due credit—to England.

In view of the considerations urged above, showing that a dollar spent in the Navy is not a dollar wasted, provided it be spent within the United States, let us hope that Congress in building an "efficient Navy" will build a large Navy. It is common to hear the opinion advanced that we need a good Navy but not a large one; that it would be opposed to our interests and contrary to our policy as a Republic to have a large Navy; and we hear it argued that what we need is a few good ships which could in time of war, serve as a nucleus around which as large a Navy could be constructed as the war might demand. This reasoning is fallacious; it would not have been fallacious twenty years ago, but it is fallacious now. Precisely the same causes as renders it wise for us to have a good Navy render it wise for us to have a large Navy.

The reasons why we need a good Navy are that our coast exposes a great many billions of dollars worth of property to anybody who chooses to destroy it; and that the great speed of modern ships, the great thickness of their armor, and the great range of their guns, together with the existence of cables under all the seas, enable any European country (and some South American countries) to concentrate a large fleet on our coasts and bombard our towns—in three weeks after declaration of war. How could a small but good Navy serve as a nucleus at such a time? Under the very best circumstances could this nucleus be developed into a sufficient Navy in three weeks?

It would require two years at least. And after the new Navy had been built, comprising large ironclads with suitable engines, guns, &c., whom would we get to manage them? Where would we get men capable of properly handling and fighting these monstrous machines full of elaborate engines, of guns of a great many types, controlled by complicated apparatus, of torpedoes, of gun-cotton, and other high explosives, &c? We could not find them in the Navy, because, granting that all the men in the Navy had not long since been killed, we only had enough men originally in the Navy for the nucleus; and the drafting of several thousand men at hazard, and the putting of them on board modern ships to manage their electrical apparatus and gun-cotton might, perhaps, be a very interesting experiment, but it can hardly be prophesied in advance that it would be a successful one.

It must be plain that the expression "a small but efficient Navy" is meaningless, because a Navy cannot for our purpose be efficient if it is small. A Navy to be efficient must fullfil the purpose for which it is intended, and as the principal purpose for which our Navy is

intended is to protect our coasts against a sudden attack by a large modern fleet, it cannot be efficient unless it can repel that attack; and to do this it must comprise a great number of armored ships, equipped with the best and latest apparatus and manned with officers and men capable of handling that apparatus.

ADVANTAGES OF NARROW-GAUGE RAILWAYS.

By AUGUSTE MOREAU.

From "Iron."

The author has for some years devoted much attention to the subject of narrow-gauge railways, and their suitability for accommodating the traffic requirements of more or less thinly-populated districts, by putting them in railway communication with the main lines. Although these railways are especially adapted to districts where the traffic is limited, they are also capable of carrying an amount —in some instances very considerable, as on the Festiniog (North Wales) Railway, where with a gauge of only two feet, the traffic receipts are £2,253 per mile per annum. This compares favorably with the State Railway of France, a line of normal gauge (4 feet 8½ inches), earning £644 per mile. As regards speed, that obtained upon the Festiniog Railway is 31 miles per hour, and, according to Mr. Fairlie, could with safety be increased to 45 miles per hour.

In France, since 1881, concessions have been granted for more than 1,864 miles of railways in outlying districts (Chemins de Fer d'intérêt local), and, in the author's opinion, there remain ten times that amount yet to be constructed of lines necessary for bringing the villages of various districts into communication with the neighboring towns and the main railway systems. These railways, however, to be remunerative, must be constructed to a gauge much less in width than that of the normal 4 feet 8½ inches, as a return of from £193 to £257 per mile per annum is at the present time regarded as a fair amount of traffic for a local line.

The cost of some of the narrow-gauge lines in other countries is given. In Norway, with a gauge of 3 feet 6 inches, the cost has varied from £3,154 to £5,342 per mile, according to the character of the country. In Sweden, where all the lines are narrow-gauge, varying from 2 feet 7 inches to 4 feet, the cost has averaged £3,862 per mile. In Brazil four-fifths of the railways are on a reduced gauge, varying from 2 feet 6 inches to 4 feet 6 inches in width, the greater part of these being to the 3 feet 3 inches (1 meter) gauge, and extending over a length of 2,983 miles. The remaining fifth (Dom Pedro II.) is to a gauge of 5 feet 3 inches (1.60 meter). The average traffic receipts of the narrow-gauge railways are £1,287 per mile per annum.

In Canada there is a length of 870 miles of railway laid to a gauge of 3 feet 6 inches. The cost of the Toronto, Grey & Bruce, forming part of this system, was, without rolling stock, £1,287 per mile. In Queensland some of the railways are of 3 feet 6 inches gauge, the speed being from 15½ to 18½ miles per hour, and the cost of construction from £5,986 to £9,977 per mile. The Ergastirian Railway (Greece), with a gauge of 3 feet 3 inches, cost, complete, £4,814 per mile, in a country so rough as to necessitate tunneling. Details are given of the permanent way and rolling stock used on the narrow gauge (2 feet 7 inches) railway between Rupertshof and Hennef, near Cologne, but the cost is not mentioned. In the French colonies the 3 feet 3 inches gauge is generally adopted, and the secondary lines of Algeria, of which there are about 3,760 miles yet to construct, will be to that gauge. A table is given showing the widths of the principal narrow-gauge lines in work or under construction in France and elsewhere, from which it may be seen that the reduced gauge most prevalent in France is 3 feet 3 inches; in Germany, 2 feet 6 inches; and in England, or those coun-

tries subject to English influence, 3 feet or 3 feet 6 inches.

The author recommends that the width of gauge best suited for adoption in constructing local lines will, with few exceptions, viz., in very thinly populated districts, where the gauge might be made 2 feet 6 inches, be found to be 3 feet 3 inches, and describes at length the economical advantages of this gauge as compared with that of the normal, viz., 4 feet $8\frac{1}{2}$ inches. In earthwork the great saving is due partly to the reduction of the formation width, but in hilly districts far more to the avoidance of heavy embankments and cuttings, through being enabled more closely to follow the natural surface of the ground, by the adoption of curves of very much sharper radius, and gradients of greater inclination. The author also demonstrates that with a gauge of 3 feet 3 inches the rolling stock can with equal ease travel over a curve of less than half the radius of the equivalent curve on the normal gauge, and that the proportion of dead load to useful load in the rolling stock, being diminished in the case of the reduced gauge, therefore the inclination of the gradients may be made steeper.

The above considerations directly influence the area of land required, and a further saving under this head is effected by the avoidance of a severance, and a reduction in the length of road and steam, diversions, &c. Bridges and culverts are similarly reduced in cube, and in many instances their necessity avoided, and the saving extends to workshops, carriage and engine sheds. As regards the permanent way, the weight of the locomotives being only from 4 to 6 tons per axle, a rail weighing from 50 to 60 lbs. per yard suffices, and the sleepers are reduced from 8 feet 3 inches to a length of 5 feet three inches or 5 feet 11 inches, and are proportionately less in cross section.

In the rolling stock the advantage procured by the adoption of the 3 feet 3 inches gauge, in diminishing the proportion of the dead to the useful load, is demonstrated as follows. Supposing all the dimensions of the two rolling stocks to be in the same proportion as the gauges, then the weight of the respective wagons will be as the cube of the gauges $\frac{p}{P} = \frac{3'\ 3''^3}{4.8\frac{1}{2}^3}\left(\frac{1.000^3}{1.445^3}\right) = \frac{1}{3}$ about, and the molecular resistance to flexure will be as the squares of the corresponding dimensions, $\frac{R}{r} = \frac{3'.3''^2}{4\ 8\frac{1}{2}^2}\left(\frac{1.000^2}{1.445^2}\right) = \frac{1}{2}$ about. Therefore the wagon of the 3 feet 3 inches gauge will only weigh one-third of that of the 4 feet $8\frac{1}{2}$ inches gauge, but will be capable of carrying one-half the load of the latter. Dividing these into one another, $\frac{1}{3} \div \frac{1}{2} = \frac{2}{3}$, therefore the portion of the dead to the useful load for a gauge of 3 feet 3 inches is two-thirds (0.666) only of what it would be for the normal gauge. In practice the diminution in the dimensions as above described cannot be strictly carried out, but the proportion of the dead to the useful load may, in the 1 meter gauge, be assumed as 0.7 of that for the normal gauge.

The author states that in England goods wagons capable of carrying 8 tons average a useful load of only 1 ton, and that, as regards passenger traffic, the number of persons actually carried is twenty-five for every one hundred seats provided. In France, as regards the goods traffic, the discrepancy is less marked, the average being 4 tons of dead weight to 1 ton of useful load; but the proportion of passengers is about the same as in England. In addition to the saving in dead-weight, the wagons of the 3 feet 3 inches gauge are also better adapted for a local traffic where the separate consignments are likely to be small in amount. The passenger carriages of the 3 feet 3 inches gauge may with safety be made 9 feet 2 inches wide, thus affording five seats in each transverse row. A single central buffer is strongly recommended for narrow-gauge vehicles, as better adapted for sharp curves. It has been suggested that the normal gauge might be preserved, and at the same time the cost of construction in rough countries be reduced to a minimum, by adopting sharp curves, worked with rolling stock of the American bogie truck type, but one great objection to this is the increase in the dead-weight of the vehicles, the proportion being 8 to 1 (with a full carriage), as compared with 3 to 1 on the 3 feet 3 inches gauge. The objections to the break of gauge, on account of the trans-shipment, may be classified under

the heads of working expenses, delay, and damage to goods. The first may be diminished to a cost of ½d. per ton, if proper arrangements are instituted. The question of delay is of little importance, as, where there is no break of gauge a day is usually lost when a truck has to pass from one system to another. With regard to damage, the higher classes of goods being as a rule in small consignments, they form only portion of a truck load, and therefore would, with an unbroken gauge, have to be transhipped at the junction; whereas, in the instance of coals and other minerals, coal, &c., their transhipment would, under this head, be of little import.

Under present conditions, at the junction of two systems similar in gauge, a transhipment always takes place of incomplete loads, and, in addition, three-fourths the amount of all merchandise arriving in full wagons.

The saving in cost of construction of a line through an easy country is at least equal to the proportionate diminution of the gauge—viz., 33 per cent., increased in a rough country to 50 per cent. or 75 per cent.

The following are the costs of a few narrow-gauge lines, compared with what they would have amounted to if constructed with the normal gauge:

	Normal Gauge.
1 meter gauge, Anzin to Calais, cost £4,956 per mile	(77,000 fr. per kilo.),
was estimated at £12,872 (200,060 fr.	").
1 meter gauge, Hermes to Beaumont, cost £4,956 per mile	(77,000 fr. per kilo.),
was estimated at £14,802 (230,000 fr.	").

Had the Corsican railways been constructed to the normal gauge, it was estimated that they would have cost from three to four times the amount actually expended upon the 3 feet 3 inches gauge.

In the Rio Grande (Denver) railway the narrow gauge cost three-fifths of what the normal would have, and the Livonia (Russian) railway, with a gauge of 3 feet 6 inches (1.067 meter), realized an economy of 40 per cent. on the estimate for the normal gauge.

In conclusion, in adopting narrow-gauge lines, the public should have every facility offered it for using them, including simplification of classes, stopping-places at the crossings of all important roads, and commissions should be given to the hotel and shop-keepers of the district for the sale of tickets. In France all the railways requiring the normal gauge have already been constructed, but there still remains an enormous length of narrow-gauge lines to be made, which, if carried out in an economical manner, would reduce the cost from £9,655 (150,000 fr.) to £12,172 per mile (200,000 fr. per kilometer) for the normal gauge, down to £3,218 or £5,150 per mile (50,000 per mile, or 80,000 per kilometer) for the 3 feet 3 inch gauge.—*Memoires de la Société des Ingénieurs Civils;* through *Proc. Inst. Civ. Eng.*

UNIVERSAL OR WORLD TIME.

Lecture by W. H. M. CHRISTIE, F.R.S., Astronomer-Royal, at the Royal Institution, March 19, 1886.

From "Nature."

CONSIDERING the natural conservatism of mankind in the matter of time-reckoning it may seem rather a bold thing to propose such a radical change as is involved in the title of my discourse. But in the course of the hour allotted to me this evening, I hope to bring forward some arguments which may serve to show that the proposal is not by any means so revolutionary as might be imagined at the first blush.

A great change in the habits of the civilized world has taken place since the old days when the most rapid means of conveyance from place to place was the stage coach, and minutes were of little importance. Each town or village then naturally kept its own time, which was regulated by the position of the sun in the sky. Sufficient accuracy for the ordinary purposes of village life could be obtained by means of the rather rude

sun-dials which are still to be seen on country churches, and which served to keep the village clock in tolerable agreement with the sun. So long as the members of a community can be considered as stationary, the sun would naturally regulate, though in a rather imperperfect way, the hours of labor and of sleep and the times for meals, which constitute the most important epochs in village life. But the sun does not really hold a very despotic sway over ordinary life, and his own movements are characterized by sundry irregularities to which a well-ordered clock refuses to conform.

Without entering into detailed explanation of the so-called "Equation of Time," it will be sufficient here to state that, through the varying velocity of the earth in her orbit, and the inclination of that orbit to the ecliptic, the time of apparent noon, as indicated by the sun, is at certain times of the year fast, and at other times slow, as compared with 12 o'clock, or noon, by the clock. [The clock is supposed to be an ideally perfect clock, going uniformly throughout the year, the uniformity of its rate being tested by reference to the fixed stars.] In other words, the solar day, or the interval from one noon to the next by the sun, is at certain seasons of the year shorter than the average, and at others longer, and thus it comes about that by the accumulation of this error of going, the sun is, at the beginning of November, more than 16 minutes fast, and by the middle of February, 14½ minutes slow, having lost 31 minutes, or more than half-an-hour, in the interval. In passing, it may be mentioned as a result of this, that the afternoons in November are about half-an-hour shorter than the mornings, whilst in February the mornings are half-an hour shorter than the afternoons. In view of the importance attached by some astronomers to the use of exact local time in civil life, it would be interesting to know how many villagers have remarked this circumstance.

It is essential to bear these facts in mind when we have to consider the extent to which local time regulates the affairs of life, and the degree of sensitiveness of a community to a deviation of half-an-hour or more in the standard reckoning of time. My own experience is, that in districts which are not within the influence of railways, the clocks of neighboring villages commonly differ by half an hour or more. The degree of exactitude in the measurement of local time in such cases may be inferred from the circumstance that a minute hand is usually considered unnecessary. I have also found that, in rural districts on the Continent, arbitrary alterations of half-an-hour fast or slow are accepted, not only without protest, but with absolute indifference.

Even in this country, where more importance is attached to accurate time, I have found it a common practice, in outlying parts of Wales (where Greenwich time is about 20 minutes *fast* by local time) to keep the clock half-an hour fast by railway (*i. e.*, Greenwich) time, or about 50 minutes fast by local time. And the farmers appeared to have no difficulty in adapting their hours of labor and times of meals to a clock which, at certain times of the year, differed more than an hour from the sun.

There is a further irregularity about the sun's movements which makes him a very unsafe guide in any but tropical countries. He is given to indulging in a much larger amount of sleep in winter than is desirable for human beings who have to work for their living, and cannot hibernate as some of the lower animals do. To make up for this he rises at an inconveniently early hour in summer, and does not retire to rest until very late at night. Thus, it would seem that a clock of steady habits would be better suited to the genius of mankind.

Persons whose employment requires daylight must necessarily modify their hours of labor according to the season of the year, whilst those who can work by artificial light are practically independent of the vagaries of the sun. Those who work in collieries, factories, or mines, would doubtless be unconscious of a difference of half-an-hour or more between the clock and the sun, whilst agriculturists would practically be unaffected by it, as they cannot have fixed hours of labor in any case.

Having thus considered the regulating influence of the sun on ordinary life within the limits of a small community, we must now take account of the effect of business intercourse between different communities separated by distances

which may range from a few miles to half the circumference of our globe. So long as the means of communication were slow, the motion of the traveler was insignificant compared with that due to the rotation of the earth, which gives us our measure of time. But it is otherwise now, as I will proceed to explain.

Owing to the rotation of the earth about its axis, the room in which we now are is moving eastward at the rate of about 600 miles an hour. If we were in an express train going eastward at a speed of 60 miles an hour (relatively to places on the earth's surface), the velocity of the traveler due to the combined motions would be 660 miles an hour, whilst if the train were going westward it would be only 540 miles. In other words, if local time be kept at the stations, the apparent time occupied in traveling 60 miles eastward would be 54 minutes, whilst in going 60 miles westward it would be 66 minutes. Thus, the journey from Paris to Berlin would apparently take an hour and a-half longer than the return journey, supposing the speed of the train to be the same in both cases.

In Germany, under the influence of certain astronomers, the system of local time has been developed to the extent of placing posts along the railways to mark out each minute of difference of time from Berlin.. Thus, there is an alteration of one minute in time, reckoning for every ten miles eastward or westward, and even with the low rate of speed of German trains, this can hardly be an unimportant quantity for the engine-drivers and guards, who have to alter their watches one minute for every ten miles they have traveled east or west. This would seem to be the *reductio ad absurdum* of local time.

In this country the difficulty as to the time reckoning to be used on railways was readily overcome by the adoption of of Greenwich time throughout Great Britain. The railways carried London (*i. e.*, Greenwich) time all over the country, and thus local time was gradually displaced. The public soon found that it was important to have correct railway time, and that even in the west of England, where local time is about twenty minutes behind Greenwich time, the discordance between the sun and the railway clock was of no practical consequence. It is true that for some years both the local and the railway times were shown on village clocks by means of two minute hands, but the complication of a dual system of reckoning time naturally produced inconvenience, and local time was gradually dropped. Similarly in France, Austria, Hungary, Italy, Sweden, &c., uniform time has been carried by the railways throughout each country. It is noteworthy that in Sweden the time of the meridian one hour east of Greenwich has been adopted as the standard, and that local time at the extreme east of Sweden differs from the standard by about 36½ minutes.

But in countries of great extent and longitude, such as the United States and Russia, the time-question was not so easily settled. It was in the United States and Canada that the complication of the numerous time standards then in use on the various railways forced attention to the matter. To Mr. Sandford Fleming, the constructor of the Inter-Colonial Railway of Canada, and engineer-in-chief of the Pacific Railway, belongs the credit of having originated the idea of a universal time to be used all over the world. In 1879 Mr. Fleming set forth his views on time-reckoning in a remarkable paper read before the Canadian Institute. In this he proposed the adoption of a universal day, commencing at Greenwich mean noon, or at midnight of a place on the anti-meridian of Greenwich, *i. e.*, in longitude 180° from Greenwich. The universal day thus proposed would coincide with the Greenwich astronomical day, instead of with the Greenwich civil day, which is adopted for general use in this country.

The American Metrological Society in the following year issued a report recommending that, as a provisional measure, the railways in the United States and Canada should use only five standard times, 4, 5, 6, 7, and 8 hours respectively later than Greenwich, a suggestion originally made in 1875 by Professor Benjamin Peirce. This was proposed as an improvement on the then existing state of affairs, when no fewer than seventy-five different local times were in use on the railroads, many of them not differing more than 1 or 2 minutes. But the committee regarded this merely as a step towards unification,

and they urged that eventually one common standard should be used as railroad and telegraph time throughout the North American Continent, this national standard being the time of the meridian 6 hours west of Greenwich, so that North American time would be exactly 6 hours later than Greenwich time.

Thanks to the exertions of Mr. W. F. Allen, Secretary of the General Railway Time Convention, the first great practical step toward the unification of time was taken by the managers of the American railways on November 18, 1883, when the five time-standards above mentioned were adopted. Mr. Allen stated in October, 1884, that these times were already used on 97½ per cent. of all the miles of railway lines, and that nearly 85 per cent. of the total number of towns in the United States of over 10,000 inhabitants had adopted them.

I wish to call particular attention to the breadth of view thus evidenced by the managers of the American railways. By adopting a national meridian as the basis of their time-system, they might have rendered impracticable the idea of a universal time to be used by Europe as well as America. But they rose above national jealousies, and decided to have their time reckoning based on the meridian which was likely to suit the convenience of the greatest number, thus doing their utmost to promote uniformity of time throughout the world by setting an example of the sacrifice of human susceptibilities to general expediency.

Meanwhile Mr. Sandford Fleming's proposal had been discussed at the Geographical Congress at Venice in 1881, and at a meeting of the Geodetic Association at Rome, in 1883. Following on this a special conference was held at Washington in October, 1884, to fix on a meridian proper to be employed as a common zero of longitude and standard of time-reckoning throughout the globe. As the result of the deliberations it was decided to recommend the adoption of the meridian of Greenwich as the zero for longitude, and the Greenwich civil day (commencing at Greenwich midnight and reckoned from 0 to 24 hours) as the standard for time-reckoning. In making this selection the delegates were influenced by the consideration that the meridian of Greenwich was already used by an overwhelming majority of sailors of all nations, being adopted for purposes of navigation by the United States, Germany, Austria, Italy, &c. Further, the United States had recently adopted Greenwich as the basis of their time reckoning, and this circumstance in itself indicated that this was the only meridian on which the Eastern and Western Hemispheres were likely to agree.

The difficulties in the way of an agreement between the two hemispheres may be appreciated by the remarks of the Superintendent of the American Ephemeris on Mr. Sandford Fleming's scheme for universal time (which was subsequently adopted in its essentials at the Washington Conference): "A capital plan for use during the millenium. Too perfect for the present state of humanity. See no more reason for considering Europe in the matter than for considering the inhabitants of the planet Mars. No, we don't care for other nations; can't help them, and they can't help us."*

As a means of introducing universal time, it has been proposed by Mr. Sandford Fleming, Mr. W. F. Allen, and others, that standard times based on meridians differing by an exact number of hours from Greenwich should be used all over the world. In some cases it may be that a meridian differing by an exact number of half-hours from Greenwich would be more suitable for a country like Ireland, Switzerland, Greece, or New Zealand, through the middle of which such a meridian would pass, whilst one of the hourly meridians would lie altogether outside of it.

The scheme of hourly meridians, though valuable as a step towards uniform time, can only be considered a provisional arrangement, and though it may work well in countries like England, France, Italy, Austria, Hungary, Sweden, &c., which do not extend over more than one hour of longitude, in the case of such an extensive territory as the United States difficulties arise in the transition from one hour section to the next, which are only less annoying than those formerly experienced, because the number of transitions has been reduced from seventy-five to five, and the change of

* Proceedings of the Canadian Institute, Toronto, No. 143, July, 1885,

time has been made so large that there is less risk of its being overlooked. The natural inference from this is that one time-reckoning should be used throughout the whole country, and thus we are led to look forward to the adoption in the near future of a national standard time, 6 hours slow by Greenwich, for railways and telegraphs throughout North America.

We may then naturally expect that by the same process which we have witnessed in England, France, Italy, Sweden, and other countries, railway time will eventually regulate all the affairs of ordinary life. There may, of course, be legal difficulties arising from the change of time reckoning, and probably in the first instance local time would be held to be the legal time, unless otherwise specified.

It seems certain that when a single standard of time has been adopted by the railways throughout such a large tract of country as North America, where we have a difference of local time exceeding five hours, the transition to universal time will be but a small step.

But it is when we come to consider the influence of telegraphs on business life, an influence which is constantly exercised, and which is year by year increasing, that the necessity for a universal or world time becomes even more apparent. As far as railways are concerned, each county has its own system, which is, to a certain extent, complete in itself, though even in the case of railways the rapidly increasing inter-communication between different countries makes the transition in time-reckoning on crossing the frontier more and more inconvenient. Telegraphs, however, take no account of the time kept in the countries through which they pass, and the question, as far as they are concerned, resolves itself into the selection of that system of time-reckoning which will give least trouble to those who use them.

For the time which is thus proposed for eventual adoption throughout the world, various names have been suggested. But, whether we call it Universal, Cosmic, Terrestrial, or what seems to me best of all, World Time, I think we may look forward to its adoption for many purposes of life in the near future. The question, however, arises as to the starting point for the universal or world day. Assuming that, as decided by the great majority of the delegates at Washington, it is to be based on the meridian of Greenwich, it has still to be settled whether the world day is to begin at midnight or noon of that meridian. The astronomers at Rome decided by a majority of twenty-two to eight in favor of the day commencing at Greenwich noon, that is, of making the day throughout Europe begin about mid-day. However natural it might be for a body of astronomers to propose that their own peculiar and rather inconvenient time-reckoning should be imposed on the general public, it seems safe to predict that a World Day which *commenced* in the middle of their busiest hours would not be accepted by business men. In fact, the idea on which this proposal was founded was that universal time would be used solely for the internal administration of railways and telegraphs, and that accurate local time must be rigidly adhered to for all other purposes. It was conceded, however, that persons who traveled frequently might with advantage use universal time during railway journeys. This attempt to separate the traveling from the stationary public seems to be one that is not likely to meet with success, even temporarily, and it is clear that in the future the latter class may be expected to be completely absorbed in the former. Another argument that influenced the meeting at Rome was the supposed use of the astronomical day by sailors. Now, it appears that sailors never did use the astronomical day, which begins at the noon *following* the civil midnight of that date, but the nautical day, which begins at the noon *preceding*, *i. e.*, twenty-four hours before the astronomical day of the same date, ending when the latter begins. And the nautical day itself has long been given up by English and American sailors, who now use a sort of mongrel time-reckoning, employing civil time in the log-book and for ordinary purposes, whilst, in working up the observations on which the safe navigation of the ship depends, they are obliged to change civil into astronomical reckoning, altering the date where necessary, and interpreting their A. M. and P. M. by the light of nature. It says something for the common sense of our sailors that they are able to carry out every day without mis-

take this operation, which is considered so troublesome by some astronomers.

In this connection I may mention that the Board of Visitors of Greenwich Observatory have almost unanimously recommended that, in accordance with the resolution of the Washington Conference, the day in the English Nautical Almanac should be arranged from the year 1891 (the earliest practicable date) to begin at Greenwich midnight (so as to agree with civil reckoning, and remove this source of confusion for sailors), and that a committee appointed by them have drawn up the details of the changes necessary to give effect to this resolution without causing inconvenience to the mercantile marine.

The advantage of making the world day coincide with the Greenwich civil day is that the change of date at the commencement of a new day falls in the hours of the night throughout Europe, Africa and Asia, and that it does not occur in the ordinary office hours (10 A. M. to 4 P. M.) in any important country except New Zealand. In the United States and Canada the change of date would occur after four in the evening, and in Australia before ten in the morning. This arrangement would thus reduce the inconvenience to a minimum, as the part of the word in which the change of date would occur about the middle of the local day is almost entirely water, while on the opposite side we have the most populous continents.

The question for the future seems to be whether it will be found more troublesome to change the hours for labor, sleep, and meals once for all in any particular place, or to be continually changing them in communications from place to place, whether by railway, telegraph, or telephone. When universal or world time is used for railways and telegraphs, its seems not unlikely that the public may find it more convenient to adopt it for all purposes. A business man who daily travels by rail, and constantly receives telegrams from all parts of the world, dated in universal time, would probably find it easier to learn once for all that local noon is represented by 17h. U. T., and midnight by 5h. (as would be the case in the Eastern States of North America), and that his office hours are 15h. to 21h. U. T., than to be continually translating the universal time used for his telegrams into local time.

If this change were to come about, the terms noon and midnight would still preserve their present meaning with reference to local time, and the position of the sun in the sky, but they would cease to be inseparably associated with 12 o'clock.

TALL CHIMNEYS.—In reference to the note on the Mechernich chimney in a recent issue, Mr. H. Stopes draws attention to two specially tall chimneys in Glasgow — Townsend's, 454 feet; Tennant's, 235 feet.

ON A NEW APPARATUS FOR MEASURING ELECTRIC CURRENTS—BY F. DE LALANDE.—This apparatus is simply formed of a bundle of soft-iron wires, placed in the interior of a metallic areometer (dydrometer), which is immersed in a test-tube filled with water, the tube being surrounded with a solenoid traversed by the current to be measured. The tube or bar of the areometer is guided through a metal eye, to prevent friction against the sides of the tube. As constructed by Mr. Carpentir, these instruments, with a displacement of 0.1 meter, show currents of 10 to 25 amperes, or a difference of potential of 100 volts. The ammeters have a resistance of 0.01 to 0.02 ohm; the voltmeters about 1,700 ohms.

IN a paper on "The Formation of Rain, Hail and Snow," recently read before the Meteorological Society by Mr. A. W. Clayden, F. G. S,. the author points out that all observations tend to show that, except under quite abnormal conditions, the temperature of the atmosphere falls as the height above sea level increases; and there seems no reason whatever for assuming that the law does not apply to that portion of the atmosphere which forms a cloud. Hence, if a drop were to be formed at or near the upper surface of a cloud, it would fall down into a region saturated with vapor at a temperature above its own. The result will be further condensation producing a larger drop; and this process will continue until it leaves the cloud. If its temperature be below the dew point of the air it falls through, condensation will continue until it reaches the ground. However, it is obvious that this subsequent gain cannot bear any very large proportion to the growth while falling through the saturated cloud, from which the conclusion follows that the size of the drop must increase with the thickness of the cloud. The author suggests that condensation begins on the upper surface of the cloud by the cooling of some of the liquid cloud particles. If this particle is cold enough it will solidify, and snow will be formed. Should it not be quite cold enough to solidify at once, owing to its minuteness, but remain still below the freezing point, hail is formed. Finally, if the temperature is not low enough for either snow or hail, rain is produced.

RANKINE'S THERMODYNAMICS.

By DE VOLSON WOOD, C.E., M.A.

Contributed to Van Nostrand's Engineering Magazine.

I.

The following lecture delivered by the writer to the Senior Class in Stevens Institute of Technology, is an attempt to explain and amplify Rankine's Thermodynamics, as presented in his work on the "Steam Engine and other Prime Movers."

Rankine's Thermodynamics is not "light reading." The subject is one demanding close study, and as presented in our textbook, it is especially difficult because obscure and "sketchy"—more so, in fact, than in his original memoirs upon the subject. In print, or in correspondence, I find such expressions as "Rankine *seems* to consider;" "Rankine *appears* to make p a complex quantity;" "The author is too difficult because obscure;" "While Rankine, if referred to at at all, only his very words are quoted, showing that their scope is not fully grasped;"* "The more theoretical and speculative parts of the investigation are diffuse and difficult of comprehension;"† and the late lamented Clerk-Maxwell observed in regard to Rankine's second law that "its meaning is inscrutable." In view of these and other facts which we might quote, added to our own experience, no apology is needed for attempting to explain in familiar language the methods of our author. But our self-imposed task is not altogether agreeable, for we have not satisfied ourself; but our effort may stimulate, or provoke, others, as the case may be, to continue the work we have begun; to the end that the *methods* of Rankine may be more generally used.

Rankine began his investigation of this subject with the "Hypothesis of Molecular Vortices," or "Centrifugal Theory of Elasticity," which assumes *that each atom of matter consists of a nucleus or central point enveloped by an elastic atmosphere, which is retained in its position by attractive forces, and that the elasticity due to heat arises from the centrifugal force of those atmospheres, revolving or oscillating about their nuclei or central points.** From this principle he deduced all the more important equations pertaining to heat—a fact which favors the correctness of the hypothesis, but does not prove that it is realized in nature. Sir William Thomson is confident that the theory does not correctly represent nature. With this, however, we have nothing to do at present, for, as our author stated in some of his later writings, the laws of thermodynamics have become thoroughly established by experiment and experience, independent of any hypothesis in regard to molecular actions.

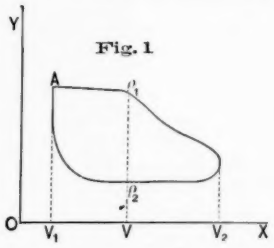
The first law—that of *the mutual convertibility of heat and mechanical work*—is readily understood as soon as the fact that *heat is a form of energy* is clearly apprehended. The manner of determining the relation between heat units and kinetic energy is clearly described in Stewart's work on Heat, and in other works, the result being that *the kinetic energy in a body weighing one pound falling 772 feet in a vacuum is the same as the heat energy necessary to raise one pound of water one degree Fahrenheit.* We here, for the sake of simplicity, discard considerations of variations of gravity due to latitude and elevation and the initial temperature of the water. It is unnecessary to add to the author's specific statement, except to emphasize the fact, that in all cases, whether external work be done or not, the disappearance of heat always produces an equivalent of work of some kind. Thus, in melting ice at 32° F., producing water at the same temperature, 142 units of heat disappear without

* Van Nostrand's *Engineering Magazine*, 1879, p. 337.
† Tait's Historical Sketch of Thermodynamics, p. 140.

* This principle was stated in a paper read before the Royal Society of Edinburgh, February 4, 1850, and published in the *Phil. Mag.* for December, 1851. As the author states, this hypothesis was first given by Sir Humphrey Davy, but no mathematical deductions had previously been made from it.

doing external work. This is equivalent to $142 \times 772 = 109624$ foot-pounds of work for one pound of ice. This heat is said to be *latent*, but in fact it is not heat; the heat having disappeared, become lost, destroyed, or, more properly,

Fig. 1.



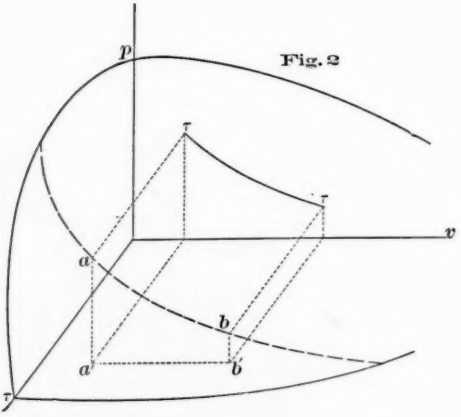
that which was heat-energy has done *work* in overcoming molecular forces, changing the molecular aggregation and producing water from ice; the effect remaining in the body, maintaining the new state of aggregation until the process is reversed, when the same amount of heat is given up in returning to ice.

In the graphic representation of the first law, the author refers only to the action of an *elastic substance*, but it is desirable to know the action for an imperfectly elastic substance. As a general rule, substances expand as they become warmer, although this rule is reversed in some special cases, as, for instance, water contracts as its temperature is increased from about 32° F. to 39° F.

It is assumed that, whatever be the nature of the substance, whether a perfect or imperfect gas, or semi-liquid, that the movement of the piston in an engine or in an indicator is due entirely to the effect of heat; and that the closed area, representing external work, has its exact equivalent in heat units. Or, in other words, the heat changed into external work is represented by the closed figure, but is no indication of the heat expended in doing internal work, such as overcoming molecular attraction, viscosity or any other force known or unknown. The indicator diagram becomes a measure of the heat transformed into work, regardless of the nature of the substance doing the work.

The thermal lines represented on page 302 of our text, are of great value in representing to the eye the relations existing between the pressure and volume of a substance when subjected to certain conditions. We find in regard to conditions dependent upon temperature, that they are also dependent upon the specific volume of the substance and the pressure to which it is subjected, or, in other words, is a function of three variables; and we may write

Fig. 2.



$$\varphi(\tau,v,p)=o,$$

or $p=f(v\tau)$, $v=f'(\tau,p)$, $\tau=f''(v,p)$;

and these may be considered as the equations to a surface in space, called a thermodynamic surface. Let the axis of volumes be a horizontal line, and of press-

ures a vertical one, both in the plane of the paper, and the axis of temperatures perpendicular to the former. If τ be constant, then

$$p=f(v)$$

will be the projection of on the plane pv of the curve of intersection of a plane parallel to pv with the thermodynamic surface: and this curve is called *isothermal.* Similarly, if τ be eliminated, giving a relation between p and v, the resulting thermal line is called *adiabatic*, or, according to Clausius, *isentropic.*

The algebraic condition for a perfect gas is (page 229 of the text)

$$pv=\frac{p_0 v_0}{\tau_0}\tau=\mathrm{R}\tau \qquad (a)$$

but if the temperature be constant, let τ_1 be that temperature, then

$$pv=\mathrm{R}\tau_1 \qquad (b)$$

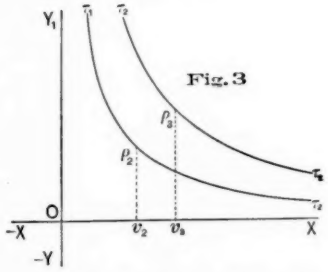


Fig. 3

will be the equation of isothermal lines, and is the equation of an equilateral hyperbola referred to its asymptotes, p and v being variables.

Let ox and oy be rectangular axes, v being measured on ox and p parallel to oy. In equation (b) let τ be any assumed value, say 500° F., then will the equation for air become

$$pv=53.15\times 500=26575;$$

but for convenience in using a scale, we will take

$$pv=4,$$

in which case the true values of p and v will be $26575\div 4$ times the values given by the figure. If $v=1$, $p=4$; if $v=2$, $p=2$; if $v=4$, $p=1$, &c., by means of which, and other values the curve $\tau_1\tau_1$, Fig. 3, may be constructed to any required degree of accuracy. Similarly, if

$$pv=9,$$

a curve represented by $\tau_2\tau_2$ may be constructed. If v be negative, p will also be negative, and the curve will be constructed on the axes $-x$ and $-y$. Both the axes, ox and oy, are asymptotic to all isothermal curves.

The formula for an imperfect gas is empirical, but taking our author's equation for carbonic acid gas, page 229, we have

$$\frac{pv}{17264}=\frac{\tau}{\tau_0}-\frac{3.42}{\tau}\times\frac{8.15725}{v} \qquad (c)$$

Let $\tau=\tau_0=493.2$; then

$$pv=17264-\frac{977}{v},\ \text{nearly.}$$

$$\therefore\ v=\frac{8632}{p}\left\{1\pm\sqrt{1-\frac{977}{(8632)^2}p}\right\}$$

This gives two values for v for every value of p, but for a large range of values

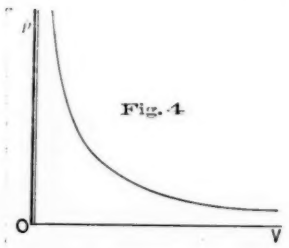


Fig. 4

of p, say from 0 to more than 50,000, the radical part will be but little less than unity, and hence one value of the parenthetical part will be but little less than two, and the other only a little above zero. The former values are represented by the heavy curve in Fig. 4, which differs but little from that of a perfect gas, and the latter by the dotted line. If the radical part be neglected the equation would become

$$v=\frac{8632}{p},$$

which is the exact law for a perfect gas at the temperature of melting ice (since it has been assumed above that $\tau=\tau_0$). If $p=o$, $v=\infty$. The value of v becomes imaginary in equation (c) for $p>\frac{(8632)^2}{977}$, or $p>76{,}300$. It is not, however, safe to rely upon extreme values in an empirical equation. Equation (c) shows that

the pressure p will be less for a given value of v, τ being constant, than if the gas were perfect.

In order to construct accurately adiabatic (or isentropic) curves, it will be necessary to anticipate their equations, which we do in order to obtain a more definite idea of their form. The exact equations of these curves are known only for perfect gases, one form of which is given on page 249 of our text, and is

$$p \propto D^{\gamma}, \text{ or } pv^{\gamma} = \text{constant}, \qquad (d)$$

where $D = 1 \div v$; and this combined with equation (a) will give the relation between p and τ, or v and τ, as given on page 319, which relations are

$$\frac{\tau}{\tau_1} = \left(\frac{v_1}{v}\right)^{\gamma-1}; \quad \frac{p}{p_1} = \left(\frac{\tau}{\tau_1}\right)^{\frac{\gamma}{\gamma-1}}; \quad \frac{p}{p_1}\left(\frac{v_1}{v}\right)^{\gamma}; \qquad (e)$$

in which $\gamma = 1.408$ for a perfect gas.

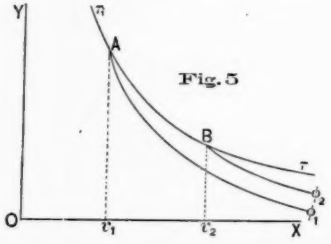


Fig. 5.

If one of these curves be made to pass through the point $p_1 = 4, v_1 = 1$, and making $\gamma = 1.4$, we have from the third of equations (e),

$$pv^{\gamma} = 4.1^{\gamma} = 4,$$

by means of which the curve $A\varphi_1$ has been constructed. If another of these curves be made to pass through $p_1 = 2$, $v_1 = 2$, we will have

$$pv^{\gamma} = 2 \times 2^{1.4}$$

by means of which $B\varphi_2$ has been constructed. The points A and B have, intentionally, been taken on the isothermal

$$pv = 4 = p_1 v_1,$$

but the curves $\varphi_1 A$ and $\varphi_2 B$ may extend above $A\tau_1$.

The isentropic (or adiabatic) relations between p and τ may be shown graphically by using the rectangular axes $o\tau$ and op, the values of τ being laid off on the former and those of p parallel to the latter. If $\tau_1 = 1$ when $p_1 = 4$, we have from the second of (e),

$$p = 4\,\tau^{3.45}$$

by means of which the curve oA has been constructed.

It is nearly a cubic parabola having Op for its axis.

Similarly, for the graphic representation for the relation between τ and v, we use Ov for the axis of the v's as before, and $O\tau$ vertical, then if the curve be made to pass through the point $v_1 = 1$ and $\tau_1 = 4$, we have, from the first of equations (e),

$$\tau v^{0.408} = 4,$$

by means of which a curve τv may be constructed.

The first and third of equations (e) are asymptotic to their respective axes, for if $v = o$, $p = \infty$ and $\tau = \infty$; and if $v = \infty$,

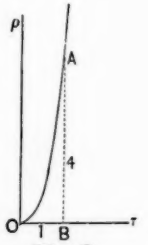


Fig. 6.

$p = o$ and $\tau = o$. These adiabatics are for perfect gases, but the general characteristics given by our author on page 302 are applicable to imperfect gases. The adiabatics for imperfect gases always slope downward more rapidly than the isothermals.

It is advisable to become familiar with the principles involved in these curves before proceeding further. For this purpose conceive that a perfect gas in the lower part of a cylindrical vessel is supporting a frictionless but perfectly fitting piston; and that the sides of the vessel including the piston and base, are perfect non-conductors of heat. If now the piston be forced downward, three things will happen: 1°, the pressure of the gas against the piston will be increased; 2°, the volume of the gas will be diminished; and 3°, the temperature of the gas will be increased. These effects are all illustrated by the line $A\varphi_1$,

Fig. 5; for in passing from a given volume v_2 to a smaller one v_1 the ordinates of the curve increase, becoming v_1A at v_1, and the temperature also increases for the curve approaches and finally intersects the isothermal line ABτ_1.

Now, reversing the operation by pulling the piston upward, or outward, and it will be found that the pressure of the gas against the piston is diminished, the volume increased and the temperature diminished. These results are also shown by the line Aφ_1, Fig. 5, passing from A towards φ_1. It is well to notice that, under the conditions imposed. if *one* of the quantities p, v, τ, be fixed, the other two also become fixed. Thus, if the temperature be maintained constant, there being no transmission of heat, it will be impossible to move the piston, and hence p and v must be unchangeable; not because it is physically impossible to move the piston, but because the piston cannot be moved without raising or lowering the temperature. Similarly, if the condition be that p shall be constant, v and τ become fixed. Here, then, is a case in which the three quantities p, v, τ, are not only mutually dependent, but are so related that a given change of one necessitates a definite change in both the others; and if one be fixed the others are as fixed as if the substance were a perfect solid. Continuing the expansion by pulling the piston outward, the pressure and temperature will continually fall, as shown by the curve Aφ_1, Fig. 5, and the first and third of equations (*e*) show that for $v=\infty$, the pressure and absolute temperature both become zero. The entire work done by the gas upon a piston during this indefinite expansion was the *intrinsic* energy of the gas at the beginning of the expansion. If, however, the gas be imperfect, the entire energy in the gas will equal the entire heat absorbed by the substance, less the internal work done upon the substance in raising it from a zero pressure to the final pressure; and is also equal to the energy which it is capable of imparting to a piston during an indefinite expansion without transmission of heat, plus the energy expended in overcoming its own molecular forces during such expansion. The *intrinsic* energy is the energy which the gas is capable of imparting to a piston without transmission of heat during an indefinitely extended expansion. In perfect gases the intrinsic energy is the entire energy, but in imperfect gases the intrinsic energy is less than the entire energy by an amount equal to the energy absorbed by the gas during the indefinite expansion.

If the "total actual heat," or simply the "actual heat" were the result of the linear motions of the molecules, then for a mass m the heat would be $\frac{1}{2}mv^2$, where v^2 is the mean of the squares of the actual velocities of the molecules of the body. To test this hypothesis, take the case of air, the specific heat of which at constant volume is 0.169, that of water being unity; and at the melting point of ice, 32° F.=493°.2 F. absolute, we have for the energy of one pound

$$k\tau = 0.169 \times 772 \times 493°.2 = 64264 \text{ foot-pounds,} \quad (f)$$

then $$\tfrac{1}{2} \cdot \tfrac{1}{32} \cdot v^2 = 64264;$$

$$\therefore v = 2033 \text{ feet per second.}$$

But it is known that the velocity of the molecules of air producing a pressure of of 14.7 pounds per square inch is less than 1,600 feet per second. In the present volume of this Magazine, page 51, equation (3), if $x=3$ (the value commonly used), $e=14.7\times144$, $\delta=w\div g$, and $w=0.08$ of a pound, then $v=1560$ feet per second; or somewhat more than $\frac{3}{4}$ the former value. The molecules, therefore, must have some motion other than rectilinear, either wholly or partly, to produce the phenomenon of heat.

Next, suppose that the cylinder admits of the passage of heat through its walls. If now the piston be gradually forced inward, the heat generated will escape through the sides of the vessel and the temperature may be made to remain constant. In this way work may be done upon the fluid at constant temperature, while the volume and pressure both vary according to the law given in equation (*b*), the volume decreasing from Ov_2 to Ov_1, while the pressure increases from v_2B to v_1A. Reversing the operation by permitting the piston to move outward, the volume will be increased, the pressure decreased, and to maintain a constant temperature heat must be supplied from an external source. According to the first law, the entire heat supplied from an external source must equal *the entire*

work done, when the temperature continues constant, and hence for a perfect gas the *external* work done will equal the heat so supplied. To show this let AB be an isothermal line, the area v_1ABv_2 will represent the external work done by the gas in expanding from Ov_1 to Ov_2; and the shaded area MbBN between the adiabatics AbM and BcN indefinitely extended, added to the area ABbA, will represent the heat supplied in doing that work. We first show that the shaded part v_1Abv_2 equals the shaded part M*b*BN indefinitely extended.

Let $$pv=a \qquad (g)$$

be the equation of AB,

that of A*b*M,

$$pv^\gamma=b \qquad (h)$$

and that of BcN

$$pv^\gamma=c \qquad (i)$$

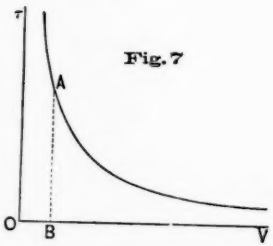


Fig. 7.

Assuming that the co-ordinates of A are known and represented by p_1 and v_1, we have $p_1v_1=a$, and since AM passes through this point its equation must satisfy the co-ordinates of the point, or $p_1v_1^\gamma=b$; hence by elimination we find

$$b=av_1^{\gamma-1} \text{ or } =a^\gamma p_1^{1-\gamma}$$

Similarly, the co-ordinates of B being p_2 and v_2, we find

$$c=av_2^{\gamma-1}=a^\gamma p_2^{1-\gamma}$$

and the equations to the adiabatics become completely known.

The area of v_1Abv_2, using equation (h), is

$$\int_{v_1}^{v_2} pdv=\int_{v_1}^{v_2} bv^{-\gamma}dv=\frac{b}{1-\gamma}$$

$$(v_2^{1-\gamma}-v_1^{1-\gamma})=\frac{a}{1-\gamma}(v_1^{\gamma-1}v_2^{1-\gamma}-1)$$

Let $p_c=vc, p_d=vd$, then from equations (h) and (i)

$$cd=p_c-p_d=(c-b)v^{-\gamma}$$

and the entire extended area will be

$$\int_{v_2}^{\infty}(c-b)v^{-\gamma}dv=-\frac{c-b}{1-\gamma}v_2^{1-\gamma}$$

$$=\frac{a}{1-\gamma}(v_1^{\gamma-1}v_2^{1-\gamma}-1) \qquad (j)$$

which is the same as that above. Hence, adding A*b*B to both gives ABv_2v_1 = M*b*ABN, the latter being indefinitely extended.

If the volume be constant the pressure and temperature may vary, and generally in the same sense; that is, if the temperature be increased the pressure will also be increased, and the thermal line on the plane pOv will be a right line parallel to Op. Similarly, if the pressure be constant, the volume and temperature may vary in the same or opposite

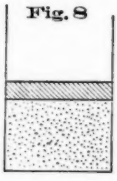


Fig. 8.

senses; but in either case the thermal line on the plane pOv will be a right line parallel to Ov. The thermal lines, in these cases, on the planes $pO\tau$ and $vO\tau$ will depend upon the algebraic relations between p, τ and v; and will be right lines for perfect gases, and curved for imperfect gases. When heat is absorbed by the fluid while external work is being done, the termal line during the performance of work may be made to assume almost any form. In Fig. 13, if the initial position of the piston be at v_1, by forcing it towards O, or allowing it to move outwards towards v_2, while the absorption of heat causes the pressure to rise, the thermal line ACB may be described. During the movement from A to C work will be done by the piston upon the fluid, the volume being diminished while the pressure and temperature were increased. The total heat supplied to a perfect gas from an external source during the operation ACB is represented by the indefi-

nitely prolonged area MACBN, where AM and BN are adiabatics.

In Fig. 14 let Bv_2 be the pressure exerted by a gas when its volume is Ov_2, and BN be an adiabatic passing through B, then if the *gas be perfect*, its entire energy will be represented by the indefinitely extended area Xv_2BM, and, conversely, the area Xv_2BN will represent the heat imparted to the fluid, while the pressure is raised from zero to v_2B, the volume being constant; but if the *gas be imperfect*, this area will not represent the heat received by the substance during the operation v_2B, since some *work* will have been expended in charging molecular conditions. Conceive a pound of this gas at the volume represented by Ov_2, and called "volume v_2" be destitute of of heat, and hence also of pressure. Let this volume remain fixed, as if it were in

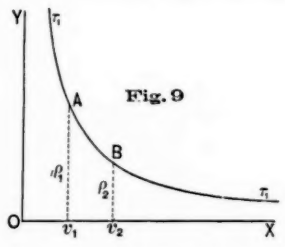


Fig. 9

a sphere, or cylinder, of unchangeable size, while the gas is heated from 0° to temperature T; then will the pressure rise from 0 to v_2b, Fig. 14. If the gas be perfect and bn an adiabatic curve, the indefinitely extended area nbv_2x will *represent* the heat supplied, the actual heat being also dependent upon the specific heat of the gas, as will appear further on. If the gas be imperfect, the heat absorbed at the same temperature, τ, will exceed the area nbv_2x by an area representing the internal work done, which is shown in Fig. 14 by the narrow shaded strip above the isothermal τ passing through b and conceived to be indefinitely extended to the right. But the pressure in the vessel containing the imperfect gas will be less than v_2b, and may be represented by v_2B; in which case the adiabatic will pass through B.

As an example of the fact that the pressure of an imperfect gas at temperature τ is less than for a perfect one at the same temperature and volume, we again take the case of carbonic acid gas, equation (*c*), which may be written in the general form

$$p=R\frac{\tau}{v}-\frac{a}{\tau v^2} \qquad (k)$$

where $R=\frac{p_0 v_0}{\tau_0}$ and $a=3.42\times 8.15725\times 17264\div 493.2$. The first term of the second member is the same as if the gas were perfect, and since a and τ are positive, the second term will be negative, making the pressure p less for the imperfect gas. Next, conceive this pound of gas at the temperature τ and pressure v_2B to be continued in a cylinder having a free, frictionless piston, and that the piston moves outward without communication of heat between the contained gas

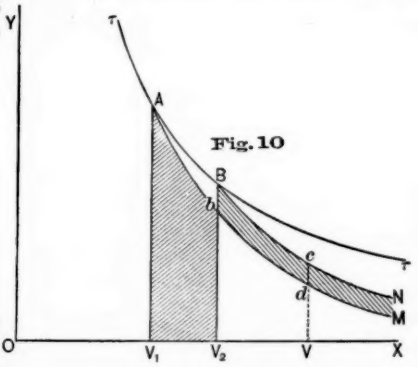


Fig. 10

and external bodies, then will the pressures for corresponding volumes be the ordinates to the adiabatic BN, and a portion of the heat of the gas will be consumed in doing work upon itself, which may be represented by an area above BN, as NB*bn* for instance.

The indefinitely extended area NBv_2X represents the intrinsic energy of the gas; and if

$k\tau$ = area nbv_2X

S = nbBN

q = the intrinsic energy,

then $q=k\tau-S$.

During the expansion along an adiabatic work is done, but no heat is supplied. Now let heat be supplied while external work is being done. Let A represent the initial condition as to pressure and volume of an imperfect gas;

then will the isothermal corresponding to this pressure pass through some higher point as a, and the area $ma\,v_1X$ indefinitely extended, will represent the total energy in the gas due to the temperature ra or pressure v_1A. Now, let the gas absorb heat, raising the temperature and pressure while the piston moves outward from Ov_1 to Ov_2, doing both external and internal work, the pressure increasing from v_1A to v_2B, the isothermal rising from some point a to another b. The internal work will depend upon the two elements—increase of temperature and expansion, and these may be considered separately, and hence will depend upon the initial and final states only. The internal work is represented by AabB, but the amount of heat required to perform this work is, as yet, unknown. Now, let the gas expand without communication of heat—or, as we

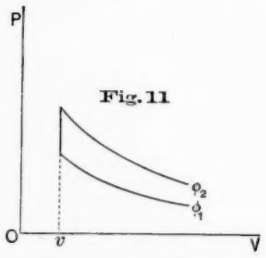


Fig. 11.

say, expand adiabatically along the adiabatic BN—to vf, it will do an amount of external work represented by v_2Bfv, and of internal work represented by $fBbh$, and since there is no communication of heat the latter must be done at the expense of the heat which was in the body at the state B. At f let the heat be abstracted until the pressure falls from f to g. We do not as yet know how much heat must be abstracted to accomplish this result, since internal work will be performed. If internal work is done when the temperature is increased, heat will be imparted to the substance from the substance itself when the temperature is decreased, so that gi will exceed fh. In this case we do not measure the temperature, and much less the heat, but the *pressures* are reduced from f on the adiabatic BN vertically down to g on the adiabatic AM. It is apparent that the further gf is removed to the right the less will be its length; or, in other words, the less will be the pressures between the adiabatics, and will vanish when removed indefinitely. The lines bn and am also approach the adiabatics as they are extended, and all these lines, bn, BN, am, AM, are asymptotic to OX. Now, compress the substance along the adiabatic gA bringing it to the condition A. During the last operation heat will be given out by the substance on account of the compression, but work will be done in the substance on account of the increase of temperature. We now have from the figure—the right hand areas being indefinitely extended,

$$nbv_2X + bv_2v_1a - nav_1X = nbam.$$

But $nbam$ represents the entire heat in foot-pounds absorbed above its initial condition. Let H_a be the entire heat in the state $A = mav_1x$, and H_b the heat in the state $B = nbv_2x$; then we have, after

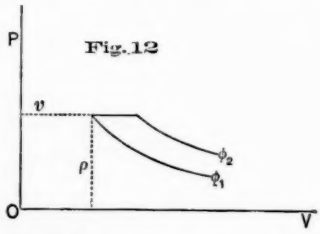


Fig. 12.

separating the former equation into other elements,

$$H_b - H_a = nb\text{BN} + \text{NB}v_2x + ba\text{AB} + \text{B}v_2v_1\text{A} - ma\text{AM} - \text{MA}v_1\text{X}. \quad (l)$$

But the work done on any substance in a cycle—that is, the work done on any substance in producing changes as to pressure, volume and temperature, but finally bringing it back to its original condition—must be zero. Hence,

$$nb\text{BN} + ba\text{AB} - ma\text{AM} = o.$$

Let

$$ba\text{AB} = \text{S}$$

$$nb\text{BN} = \text{S}_b$$

$$ma\text{AM} = \text{S}_a$$

then, the preceding equation gives

$$\text{S} = -\text{S}_b + \text{S}_a \quad (m)$$

and equation (l) becomes

$$H_b - H_a = \text{NB}v_2\text{X} + \text{B}v_2v_1\text{A} - \text{MA}v_1\text{X} = \text{MABN}$$

or,

The mechanical equivalent of the heat absorbed (or given out) by a substance in passing from state A *to state* B, *is represented by the area included between the curve* AB *and two adiabatics through* A *and* B, *and indefinitely prolonged in the direction representing increase of volume.*

This is the THEOREM on page 303 of the text.

Also, let

$$v_1 \mathrm{AB} v_2 = \int p dv$$

and equation (*l*) becomes

$$\mathrm{H}_b - \mathrm{H}_a = \mathrm{N}\mathrm{B}v_2\mathrm{X} + \int p dv - \mathrm{M}\mathrm{A}v_1\mathrm{X}$$

which is the equivalent of equation (2), page 305 of the text.

But to put it more nearly in the *form* of that equation, let

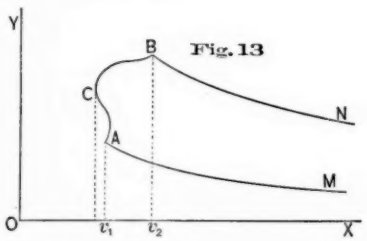


Fig. 13

$\mathrm{Q}_b = nbv_2\mathrm{X}$ = the total heat in the substance in the state B,

$$\mathrm{Q}_a = mav_1\mathrm{X},$$

then equation (*l*) becomes

$$\mathrm{H}_b - \mathrm{H}_a = \mathrm{Q}_b + \mathrm{S} + \int p dv - \mathrm{Q}_a,$$

which, combined with equation (*m*), gives

$$\mathrm{H}_b - \mathrm{H}_a - \int p dv = \mathrm{Q}_b - \mathrm{Q}_a - \mathrm{S}_b + \mathrm{S}_a \quad (n)$$

This is equation (2), page 305, except that the signs of S_b and S_a are the reverse of these here given, but this is not vital, since the author in this place has simply assigned the *form* of the expression without determining the signs of these terms. The correct sign, however, is prefixed by the author on page 313 of the text. Those who can follow the steps of the author and be convinced of the correctness of the reasoning when applied to imperfect fluids, do not need the detailed work here given.

The author now finds it necessary to introduce another principle in order to find a measure of work, including the internal as well as the external, and this is involved in his SECOND LAW. It may be stated in different forms, but the idea involved may be thus analyzed:

1°. Energy, like any other quantity, may be divided into an indefinite number of indefinitely small equal parts.

2°. Any one of the equal parts will do the same amount of work, and in doing work each does its proportionate share of the entire work.

3°. In a homogeneous substance, the total work done is the sum of all its parts.

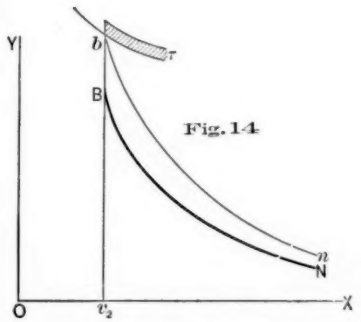


Fig. 14

The author has such an abstract way of stating some of his general propositions that we would often be in doubt how to apply them had he not given samples. In this case he has given us his "symbolic expression" of his law, and it amounts substantially to this:

To find the rate of doing work, both external and internal, per unit of heat.

But this is anticipating, somewhat, the further development of the subject.

The author restricts his definition to the case of a homogeneous and uniformly hot body, and this condition may be complied with in the analysis by considering, at first, only an infinitesimal portion of the substance, and then extending it to so much of the finite portion as is included within the conditions. The author, on page 308 of our text, states that it is applicable to heterogeneous masses. The term "hot" applies to so much of the heat which has been absorbed by a body as is retained in a condition for doing work, the heat which has al-

ready done internal work not being considered. When applied to perfect gases, in which increments of pressure are equal for equal increments of temperature at any and all points of the scale of temperature, the law appears to be sufficiently evident, and is, at least, free from difficulty; but not so when applied to imperfect gases. Rankine's statement of the second law is *quantitative*, and in this respect is superior, as a working basis, to the principle stated by Clausius and Thomson. Clausius says "heat cannot without compensation pass from a colder to a hotter body," which is a *qualitative* statement and destitute of a basis for measuring the quantity which may pass from one body to another.

Rankine recognizes this principle of Clausius as a property of heat (see page 224 of our text). Thomson states his principle thus: it is impossible to work a heat engine at a lower temperature than that of the lowest temperature of surrounding objects; but this rather gives a limit than a basis for measurement.

In illustrating this law we first make use of a rigid body in motion, an example suggested by our author on page 306. Let M be the mass of the body having a velocity v, doing work by sliding along a rough horizontal plane; and, in order to simplify the problem, assume that the only work done is in overcoming friction (no internal work), and that the friction is uniform (similar to that of a homogeneous and uniformly hot body). The kinetic energy of the body will be $\frac{1}{2}Mv^2$, which we assume is all consumed in the distance AB. The work done will be the resistance per unit of length into the distance AB, which call U; then

$$U=\tfrac{1}{2}Mv^2, \text{ also}=Q.$$

Now, let the entire mass undergo an indefinitely small change of velocity, during which it moves over the indefinitely small space Aa, then

$$dU=\tfrac{1}{2}Md(v^2)=Mvdv=dQ.$$

Next, let the body be divided into an indefinite number of indefinitely small parts, each being dM; the energy of each one of these parts will move the entire body over an indefinitely small, but proportional part, of Aa, and we have

$$d(dU)=dM\,.\,d(\tfrac{1}{2}v^2),$$

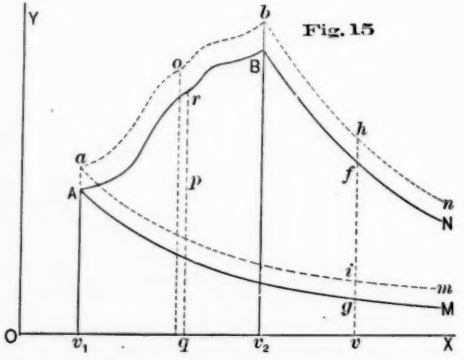


Fig. 15

and the rate of doing one of these small parts of work per *unit* of energy will be

$$\frac{d(dU)}{dQ}$$

and hence for the total energy the work done will be Q times as much, or

$$Q\frac{d(dU)}{dQ} \qquad (o)$$

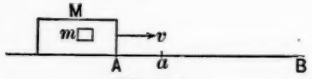


Fig. 16

It is true that this analysis, followed out, will lead to an identity, as it ought, since all the energy is here transformed into external work, and in this respect is similar to the case of work done by a perfect gas. This example may be useful

in fixing our ideas since it deals with terms and quantities with which we are already familiar. We notice that du is due to an infinitesimal change of the mass of the entire body and $d(du)$ to an infinitesimal part of the body.

The notation used by the author, viz.:

$$\delta Q \cdot \frac{d}{dQ} dU$$

is not common in elementary works on the calculus, but is frequently used in higher works. The d above the bar extends its power of differentiation to all of the quantity following the bar, so that it is here equivalent to

$$\delta Q \cdot \frac{d(dU)}{dQ} = \delta Q \cdot \frac{d^2U}{dQ}$$

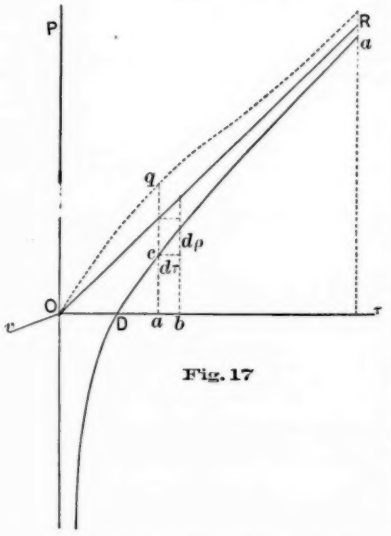


Fig. 17

When the external work is not a function of x and y, Clausius makes a distinction between

$$\frac{d}{dy}\left(\frac{du}{dx}\right) \text{ and } \frac{d^2u}{dydx},$$

but we shall have no occasion to make even this distinction; hence, we may, if we choose, use d^2U for $d(dU)$, as our author did in some of his original papers, The author, in his Memoirs, also wrote dQ in place of the δQ of our text, and here is no advantage in the latter over the former; although both are correct, as we shall soon see, so that the expression may be written

$$dQ\frac{d^2U}{dQ},$$

which, as it stands, is equivalent to d^2U, still the *form* is a convenient one for use.

If p be the normal pressure against the interior of the vessel, and the vessel be enlarged an elementary amount, dv, then will an element of the external work be

$$dU = pdv,$$

and, considering v as the independent variable, we have, by differentiating again

$$d(dU) = dpdv,$$

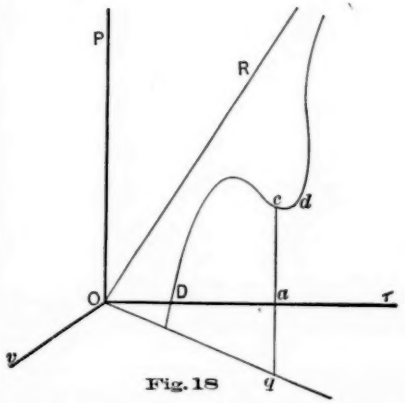


Fig. 18

where the parenthesis might be retained to indicate that the second differential is not made in reference to the same variable as the first, but this is unusual and unnecessary. Substituting the last equation in the general one, we have

$$dQ \cdot \frac{dp}{dQ} dv,$$

and this is a more convenient form for discussion than expression (o), and is identical with the form used by the author in some of his original papers. In this case pdv is an element of work due to a small variation in the entire heat, while $dpdv$ is an element of work due to a small variation in an elementary amount of heat.

This being the work done by the heat dQ, then since by *the second law* every

dQ from zero to Q does the same amount of work, the elementary work done by the total heat Q is

$$Q \cdot \frac{dp}{dQ}\, dv.$$

Since Q is the sensible (or *actual* heat) only, and the *absolute* temperature, τ, is made proportional to the quantity of sensible heat, we have

$$Q : \tau :: dQ : d\tau,$$

or

$$\frac{Q}{dQ} = \frac{\tau}{d\tau},$$

and the former expression becomes

$$\tau \frac{dp}{d\tau}\, dv$$

which form is given by our author in the *Philosophical Magazine*, 1854, (2), page 357. These forms are all equivalent, and we may write

$$Q \frac{d}{dQ} dU = Q \frac{d^2U}{dQ} = \tau \frac{d}{d\tau} dU = \tau \frac{dp}{d\tau}\, dv,$$

the last of which is the most convenient for discussion, since in it we may consider one element at a time, whereas, if U be used, we have to consider a complex quantity involving force, v, and space, v.

Returning now to page 306 of the text, we find that the author says, "It is required to find how much of this work is performed by the disappearance of heat."

If this expression be correct and exact, it is to us unintelligible; or we do not understand the "scope" of the words. If we had no means of determining the author's meaning except our text, we would expunge the words "of this" so that the sentence would read, "how much work is performed by the disappearance of heat," for then it would be in exact harmony with the text. Only four lines below the above sentence, the author says, "will cause to be performed the quantity of work," and only two lines further the author says, "the quantity of work performed by the disappearance of heat will be," which is precisely what the original expression becomes when the words "of this" are canceled; and again on page 310, "then the work performed by the disappearance of heat is," and all these expressions refer to the same thing.

In no other place in the text is there any intimation that all of the work performed is not done by the disappearance of heat, and both the language and analysis authorize us to cancel these words, and we may safely do so. On the other hand, we are slow to admit that they were inadvertently inserted, and we find, upon consulting his original paper, that he there uses the same expression. Some have suggested that Rankine had in mind the fact that work was done by this substance on account of some other agency than heat, such, for instance, as electricity, or magnetism, or some other agent unknown. To us it seems impossible to separate the effects of unknown agents by the process of logic which he uses. But we are not left in doubt on this point. In his Miscellaneous Scientific Papers, page 221, he says: "Let a homogeneous substance possess a quantity Q of a particular kind of actual energy, uniformly distributed, and let it be required to determine the amount of the effect arising from the actual energy, which tends to perform a particular kind of work by the variation of a particular passive accident." It is only a "particular kind of actual energy" that is considered in producing a particular kind of work.

Again, on page 311, it says "part of pdv is produced by molecular attractions and repulsions . . . it is not the direct effect of heat, although they may be modified by heat. . . . It is required to determine how much of pdv is the effect of heat." One would infer from these statements that only a part of pdv is produced by heat, and yet in the analysis following the remarks, it appears that the heat which produces the external work pdv also does internal work in addition. If the expression "how much of this," means "how many times this," it becomes consistent. It is possible that the author, at that time, entertained the view, that there were molecular repulsions independent of heat, as was supposed to be shown by the fact that the zero of the gas thermometer did not coincide with the zero of the absolute scale.

From the data at his command he found that the zero of the absolute scale was three or four degrees below that of the zero of an air thermometer graduated according to Fahreneit scale. (Professional Papers). But the experiments of Regnault showed that the two zeros

practically coincide. Whatever be the idea originally contained in the expression with the words, "of this," retained, it is certain that, with our present knowledge of the subject, they may be expunged.

Returning now to the consideration of the subject, the proposition is, let unity of weight of a homogeneous substance, possessing the actual heat Q, or absolute temperature τ, undergo an indefinitely small change (of volume, for instance) so as to produce the indefinitely small amount of work $dU=pdv$; it is required to find how much work (both external and internal) is done by the disappearance of heat. Let the temperature be maintained constant by heat supplied to the substance from an external source while the volume is enlarged by the amount dv, then will the heat disappearing equal the amount supplied.

This is the author's mode of treatment. On page 310 of the text he says, "In determining that function . . . it is first to be investigated as if the temperature were constant, and then the law of its variation with absolute temperature be found;" and in his paper on the Mechanical Action of Heat: "and let us investigate how much heat becomes latent or is converted into mechanical power, during this process (which consists in expanding an amount dv); the thermometric heat *being maintained constant* so that the heat which disappears must be supplied from an external source." (Professional Papers, page 311).

Considering the volume constant, the rate of increase of the pressure per degree of temperature at the temperature τ will be according to the calculus,

$$1^\circ\frac{dp}{d\tau},$$

and since each of the $d\tau$'s in 1° will, according to the Second Law, produce the same increment of pressure, we have for the pressure produced by $d\tau$

$$d\tau\frac{dp}{d\tau}, \qquad (m)$$

which is quite evident since the expression is equivalent to dp; and similarly for an element $\delta\tau$, which may be different from $d\tau$, we have for the same reason,

$$\delta\tau\frac{dp}{d\tau},$$

but which is not equivalent to dp, and for the same reason, for all the elements in τ, we have the pressure

$$\tau\frac{dp}{d\tau},$$

which, for an enlargement dv, will perform the work

$$\tau\frac{dp}{d\tau}dv,$$

and since the temperature has been maintained constant, this work expressed in thermal units will give the heat which disappeared. To test this result, first, take the case of a perfect gas, for which we have

$$\frac{dp}{d\tau}=\frac{p}{\tau},$$

which, substituted above, gives

$$\tau\,.\,\frac{p}{\tau}dv=pdv,$$

the well known expression for an element of work.

If the substance be an imperfect gas then is $\frac{dp}{d\tau}$ generally greater for any finite value of τ than it would be if the substance were a perfect gas at the same temperature. First, take carbonic acid gas, for which we have equation (e), or

$$pv=\mathrm{R}\tau-\frac{a}{\tau v},$$

Differentiating, regarding v as constant, we have

$$\tau\left(\frac{dp}{d\tau}\right)_v=\mathrm{R}\frac{\tau}{v}+\frac{a}{\tau v^2}=p+\frac{2\,a}{\tau v^2}$$

If the substance were a perfect gas we would have $\tau\frac{dp}{d\tau}=p$, but in this case the result is greater than for a perfect gas by the amount of the second term, or $\frac{2\,a}{\tau v^2}$. The same general result would follow from our author's more general equation of an imperfect gas, page 229, which is

$$\frac{pv}{p_0v_0}=\frac{\tau}{\tau_0}-\mathrm{A}_0-\frac{\mathrm{A}_1}{\tau}-\frac{\mathrm{A}_2}{\tau^2}-\&c.$$

But we will arrive at the same general result from more general reasoning. Thus, experience shows that the higher the temperature the more gaseous do all

known substances become. In some cases the temperature must be very high before the solid becomes a liquid, and very much higher before it will vaporize; still the fluidity continues to increase with increase of temperature, and we assume that if the temperature could be sufficiently high the substance would ultimately be reduced to a gaseous condition. There being internal work, the pressures due to heat at low temperatures will be lower than if the heat had not that work to do, in other words, less than if the substance were a perfect gas; hence, the pressure starts lower at a given low temperature than if it were a perfect gas, but reaches the same value at very high temperatures. Between these low and high temperatures, therefore, the range of pressures is greater for the imperfect gas than for the perfect; and hence the increments of pressure in the latter case must exceed those in the former. These principles may be illustrated by means of a diagram. Let Oτ be the axis of temperatures, and Op, of pressures. For a perfect gas we have, equation (a),

$$p=\frac{\mathrm{R}}{v}\tau$$

which may be represented by a right line OR, though the origin, O, v being constant

For an imperfect gas we conceive that it requires some heat to induce any pressure, so that for $p=o$, we have a finite value for τ giving a point D and that additions of heat causes a rise in pressure giving the line Da which approaches more and more nearly to OR as the temperature increases. In the case of carbonic acid gas, making $p=o$, we find

$$\tau=\sqrt{\frac{b}{av}},$$

which equals oD; but empirical equations cannot be trusted to such an extreme.

Divide $o\tau$ into any number of small equal parts, each equal $d\tau$, and erect ordinates to OR intersecting Da; then will each dp for the curve Da exceed that for the line oR. The expression

$$\frac{dp}{d\tau}$$

is, in the language of the calculus, a rate, which, being written out fully, is in this case—*the pressure which would be produced by a unit of temperature provided the rate remained uniform as at the beginning of the pressure.* This may be written

$$1^{\circ}\frac{dp}{d\tau},$$

which is the increase of pressure for 1° at the rate

$$\frac{dp}{d\tau},$$

and, as before stated, we deduce the expressions

$$d\tau\frac{dp}{d\tau},\quad \delta\tau\frac{dp}{d\tau},\quad \tau\frac{dp}{d\tau}.$$

Now, let the volume vary by an amount dv, while the temperature τ is maintained constant by a supply of heat from an external source, then will

$$d\mathrm{W}=\tau\frac{dp}{d\tau}dv=\tau\frac{d(d\mathrm{U})}{d\tau}$$

be an element of work done, both external and internal when τ is the absolute temperature and p the external pressure. This expression is fundamental, lying as it does at the very foundation of our author's analysis; we, therefore, dwell upon it. At least, one writer of good repute failed to get a correct conception of this expression, for he says "Rankine, however, seems to apply this law to determine the rate at which external work will be performed,"* and having this misunderstanding he attempted to enlarge the Second Law so as to make it include internal work; but Rankine left no doubt as to his meaning on this point, for in an article in *The Engineer* of June 28, 1867, he says: "This law is capable of being stated in a variety of forms, expressed in different words, although virtually equivalent to each other. The most convenient form for the present purpose appears to be the following:

To find the whole work, internal and external, multiply the absolute temperature at which the change of dimensions takes place, by the rate per degree at which external work is varied by a small variation of the temperature.

Had the author expressed himself as clearly in our text as in the above quota-

* *Van Nostrand's Magazine*, 1879, p. 337.

tion, students would have been saved much perplexity. In this statement *the rate* is between work and temperature, and in this form agrees with the text, and may be written:

$$\frac{d(du)}{d\tau}=\frac{dpdv}{d\tau}.$$

But, as before stated, the idea of work is more complex than that of pressure, since work is compound, being composed of two elements, pressure and space. We have, therefore preferred the form

$$\frac{dp}{d\tau}dv$$

and considering $\frac{dp}{d\tau}$ as the rate, v being considered as constant at first, then τ constant when v varies. It may be asked, "how can $\frac{dp}{d\tau}$ have a finite value when τ is considered constant?" It is only necessary to observe that $\frac{dp}{d\tau}$ is first found on the supposition that p varies with τ, and *afterwards* any value of τ may be assumed and fixed; or $\frac{dp}{d\tau}$ is the rate at which p was varying when τ was fixed.

Fig. 17 shows that for a given temperature the pressure is less for an imperfect gas than it would be if the same gas were perfect. In that figure $\frac{dp}{d\tau}$ may be considered as the tangent of the angle which a tangent line to the curve of pressures and temperatures makes with the axis of temperatures at the point whose abseissa is τ; and this trigonometrical tangent multiplied by τ gives an ordinate aq which being multiplied by dv gives an element of the work done, both external and internal. In this illustration a tangent to the curve Aca makes a greater angle with $o\tau$ than does oR, and the locus of q will be above OR.

We have

$$cq=aq-ac=p'-p=\tau\frac{dp}{d\tau}-p,$$

and the internal work for an infinitesimal enlargement of the volume, dv, will be

$$ds=\left(\tau\frac{dp}{d\tau}-p\right)dv,$$

$$\therefore\ s=\int\left(\tau\frac{dp}{d\tau}-p\right)dv,$$

which is equation (1A) of article 247, page 313 of the text. This is a partial differential equation in which we have thus far considered τ as constant, but making both τ and v independent variables, we have from the theory of differential equations the two partial differential equations

$$\frac{ds}{dv}=\tau\frac{dp}{d\tau}-p, \qquad (p)$$

$$\frac{ds}{d\tau}d\tau=\int\left\{\tau\frac{d^2p}{d\tau}+d\tau\frac{dp}{d\tau}-dp\right\}dv\frac{d\tau}{d\tau}$$

$$=\int\tau\frac{d^2p}{d\tau^2}dv\,.\,d\tau. \qquad (q)$$

Returning to our fundamental expression

$$\tau\frac{dp}{d\tau}dv,$$

it is stated on page 308 of our text that it may be negative, in which case Da, Fig. 17, will not be continuously convex in one direction, but may change its concavity as in Fig. 18, and we may have in the vicinity of such a point the values

$$-dp,\quad dp=o,\quad +dp,$$

and hence—since τ is never negative

$$\tau\frac{dp}{d\tau}=-,\ \tau\frac{dp}{d\tau}=o,\ \tau\frac{dp}{d\tau}=+$$

Thus, in the case of water from 32° to about 39° the internal pressure decreases, giving out, instead of absorbing heat. If through o a line be drawn parallel to the tangent at c, and ca be prolonged to meet it at q, we have

$$\tau\frac{dp}{d\tau}=-aq$$

and the internal work will in

$$(-aq-ac)dv=-cq.dv,$$

which, being negative, transforms it into external work.

If the substance be not homogeneous nor uniformly hot we have

$$W=\tau'\int\frac{dp'}{d\tau'}dv+\tau''\int\frac{dp''}{d\tau''}dv+$$

$$\&c=\Sigma\tau\int\frac{dp}{d\tau}dv,$$

in which each term is to be applied to so much of the substance as may be considered homogeneous and uniformly hot.

ENGINEERING NOTES.

THE GREAT ALPINE TUNNELS AND SUBTERRANEAN TEMPERATURES. — Among the many difficulties encountered in the execution of the works connected with the St. Gothard Tunnel, one of the greatest was the prevalent high temperature in the central section, 5 kilometers in length. The maximum temperature observed in carrying out the Mont Cenis Tunnel was 29.5° Centigrade (85° Fahrenheit), while a mean temperature of 29° (84.2° Fahrenheit) was confined to a section of 500 meters in the middle of the tunnel. During the execution of the St Gothard Tunnel, at a distance of 4½ kilometers from the southern end, and at 5½ kilometers from the northern extremity, this temperature had been already attained, and at the time when through communication was established (February 29, 1880), the mean heat, extending over a section of the works, 5 kilometers in length, had risen to 31° (87.8° Fahrenheit), and on several occasions attained the maximum temperature of 35°. The air, which was considerably rarefied and much laden with moisture, proved very injurious to health—as many as 60 per cent. of the staff being on the sick list—while the horses died at the rate of 10 per month at each end, from a species of lung disease. As a necessary consequence the wages had to be raised 25 per cent., the working hours were reduced from seven to five per diem, and the costs were enormously increased. The limit of temperature at which underground work is still possible could not with certainty be ascertained. According to Du Bois-Reymond it may be assumed that at 50° (122° Fahrenheit), in air saturated with moisture, prolonged existence becomes impossible, though it appears very probable that even at 40° (104° Fahrenheit) this may be the case. The opinion of Dr. Giaconne that in the above works the limits of human endurance had been reached was shared by the staff.

The common law of increase of temperature in proportion to depth does not apply in tunnel construction; Dr. Stapff has, from observations on the St. Gothard Tunnel, propounded the theory that the increase of temperature above the mean temperature at the earth's surface, is represented by the formula $t=0.02068\,h$, or $t=0.02159\,n$, where h is the perpendicular height of the superincumbent mountain, or n is the distance inwards of a given point, on the plane passing through the longitudinal section. Stockalper has, in a different way, calculated the temperatures likely to be encountered in carrying out the Simplon and Mont Blanc tunnels as follows, reckoning from the northern end:

SIMPLON.

(About 22 kilometers in length.)

				Probable temperature. (Centigrade).
4.0 kilometers in	and a height of		1,400	30°
6.5	"	"	1,000	33°
9.0	"	"	2,050	36°
14.7	"	"	680	31°
17.0	"	"	1,734	31°
18.0	"	"	1,100	25°

MONT BLANC.

(18.5 kilometers in length from Taconnaz to Prés, St. Didier.)

			Probable temperature. Meters.	°
4.0 kilometers in	and a height of		1,550	33
5.0	"	"	2,800	50
6.0	"	"	3,000	53.5
8.0	"	"	2,600	46
10.5	"	"	1,450	31
13.0	"	"	200	15

From these calculations he is persuaded that the execution of these tunnels will be impracticable on the systems hitherto adopted, and that it will be necessary to take very special precautions to guard against these excessive temperatures. Among other plans to be employed he mentions a bratticing to convey in air along the floor of the tunnel, use of compressed air for boring, introduction of ice into the workings, as also of streams of cold water; employment of quick lime to absorb the moisture, &c.; and he concludes that though it may be possible under certain conditions to execute the projected tunnel through the Simplon, the possibility of carrying out the proposed Mont Blanc Tunnel, under any circumstances, is open to the gravest doubt.—*Abstracts of Institution of Civil Engineers.*

MEKARSKI'S COMPRESSED-AIR ENGINES ON THE NANTES TRAMWAYS—By EDMOND BOCA.—Mekarski's system of employing compressed air, heated by an admixture of steam, for the propulsion of tramcars has been in operation at Nantes for some years. The air compressors and saturating heaters are of the kind usually employed by the patentees. A comparison of the compressed air supplied to the car engines with the capacity of the compressing cylinders shows the efficiency of the air compressors to be 76 per cent. One kilogram (2.2048 lbs.) of air compressed to 30 kilograms (426 lbs. per square inch) supplies energy equivalent to 125,000 kilograms, or 90,375 foot-pounds, and 100 kilograms are sufficient to propel a car of 8 tons weight for a distance of 12 to 14 kilometers (7.45 to 8.69 miles). The packing of the pistons of the second compressors proved troublesome, hard rubber rings and lignum vitæ did not stand, but satisfactory results have been obtained with manganese bronze. The tramcars at Nantes contain seats for 19 persons, a platform holding 15 or 16 at one end, and the heater and driver's cab at the other. The total length is 23 feet 3 inches, of which the heater and driver's platform absorb one-seventh; the width is 7 feet 2⅞ inches. The total weight is 6 tons empty, and 8 tons filled, while the weight utilized for adhesion is 4½ tons. The air is contained in ten cylindrical reservoirs placed underneath the platform, connected by pipes in two sets to form a working and a reserve battery. The contents of the former are 70 cubic feet, of the latter 28 cubic feet, holding together 220 lbs. of air at 426 lbs. pressure. The engines are attached to the outsides of the underframes, and enclosed in sheet iron covers. Their diameter is 5¼ inches, and the stroke 10¼ inches, and the cut-off takes

place at one-third of the stroke. The driving-wheels are 27⅝ inches diameter. The cars are fitted with a Stilmant brake, worked by compressed air. The heater is placed vertically on the platform, and has a capacity of 27.7 gallons, the water being heated to 150° Centigrade by means of an injection of steam previous to starting. By connecting the car reservoirs with the stationary accumulators a pressure of 20 to 25 kilograms is obtained in the former, which are then connected directly to the compressing pumps, and the pressure brought to 30 kilograms, an automatic regulator turning the air again into the fixed accumulators when this limit has been reached. According to the state of the weather and the ability of the driver, the consumption of air varies, good drivers using at Nantes about 23 lbs. per mile, while inefficient men use up to 28.40 lbs. In 1883 the average consumption was 25.9 lbs., and during the first half of 1884, 24.6 lbs. The mean results obtained during the three years, 1881 to 1883, are given in the Table below:

	1881.	1882.	1883.
Car journeys	5,582	5,338	5,543
Kilometers run	701,934	384,324	397,066
Cost per kilometer:	F. C.	F. C.	F. C.
Drivers' wages	0.060	0.062	0.061
Staff at stations	0.067	0.065	0.056
Fuel	0.117	0.117	0.101
Water	0.019	0.020	0.020
Lubrication of rolling plant	0.010	0.011	0.013
Lubrication of fixed plant	0.007	0.007	0.006
Maintenance of rolling plant	0.064	0.092	0.093
Maintenance of fixed plant	0.020	0.028	0.024
Sundries	0.008	0.006	0.004
Total	0.372	0.408	0.378

or 5.67, 6.25, and 5.76 pence per mile, respectively.

During the first half year of 1884 the cost of fuel decreased to 7.9 cents, and the total cost to 34.3 cents per kilometer, or to 5.22 pence per mile. The cost of horse traction of the three omnibus companies at Paris during the same three years was 0.612, 0516, and 0.513 cents per kilometer, or 9.39, 7.91, and 8.32 pence per tramcar-mile. This, however, includes a charge for renewal of horses, while it is not evident from the Table whether the maintenance of plant comprises a depreciation to provide for its eventual renewal, though the variations in the amount seems to indicate that depreciation or interest have not been taken into account in the calculation of the cost of traction.—*Abstracts of the Institution of Civil Engineers.*

IRON AND STEEL NOTES.

British exports of iron and steel to all countries in March aggregated 255,210 gross tons, as compared with 260,427 tons in March, 1885. A more favorable showing is made when the figures are compared with the previous months of this year, the exports in January having been 217,988 tons, and in February 225,475 tons. The exports of British iron and steel to the United States in March reached 57,684 gross tons, against 48,009 tons in February, and 48,496 tons in January. In the first quarter of this year 154,189 tons have been shipped to this country, as compared with 85,214 tons in the corresponding period of 1885. The increase is principally in pig iron, old iron, tinplates, and steel billets, slabs, etc.

On the 14th of April an Eastern syndicate, Messrs. Matthew and John Graff, of Pittsburgh, purchased the Fort Pitt Iron and Steel Works, at Pittsburgh, for the purpose of engaging in the manufacture of steel by the direct graphite process invented by Dr. C. J. Eames. By this process iron ore is broken into small pieces and mixed with 20 per cent. of Rhode Island graphite, a substance which heretofore has had no commercial value. The mixture is then placed in an ordinary heating furnace and reduced to a spongy mass at a low temperature, and it is claimed that the phosphorus and other impurities flow off with the slag. The experiments made the past winter have shown that it is only necessary for the sponge to be placed in pots and heated for a few hours, when it is ready for use. In all about ten hours are required to make good steel. The saving is so great that the new company is certain that the future is secure. Some improvements are to be made in the works, but it is expected that they will be ready for operation in the fall.—*The Bulletin.*

The Physical Constitution of Cast Steel.—Some interesting experiments with regard to the cellular structure of cast steel have been carried out at the Creusot works by M. Osmond and M. Werth. The experimenters found that, if the thinnest conceivable sheets of the metal are placed on glass and covered with nitric acid, the iron will be dissolved, while the skeleton remaining, revealing the distribution of the carbon in the steel, will, on examination by the microscope, furnish undoubted evidence that such distribution is by no means uniform, and that the cast steel consists of minute granulations in soft iron, separated, for the most part, by partitions made up of a different substance, a carburet of iron. In other words, cast steel is cellular in structure, the iron constituting the kernel, and the carburet of iron the shell. The elementary or simple cells thus constituted come together in composite cells or separate agglomerations in the thin sheets, which are thus rendered transparent by empty lines. These latter represent closed polygons of relatively large dimensions in the cast steel, but the polygons become smaller and broken up inproportionate to the more perfect manipulation of the metal.—*Iron.*

RAILWAY NOTES.

Lighting Railway Trains by Electricity—By Gustave Richard.—The object of

this paper is to enumerate and describe the several ways in which it has been proposed to regulate and direct the movement of a dynamo when set in motion by power transmitted from the axles of railway-carriage wheels, so that this movement shall not be affected by the speed of the train or by the direction in which it is running. In the opinion of the author, the easiest way to drive a dynamo, independently of the movement of the train, would no doubt be to work it by means of a special and separate steam engine placed on the locomotive itself, and he thinks it probable that such will be the plan ultimately adopted for lighting complete trains; but amongst the systems hitherto tried he declares his preference for those which consist in placing accumulators in the guard's van, in addition to the dynamo deriving its power from the rotation of the wheels of the van in which it is used.

When it is not proposed to use either commutators or special regulators of the current, the first condition which requires to be met is the securing a constantly uniform rotation of the dynamo, whether the train be running forward or backward. Rogers (John Banting, 1881) proposed to effect this by means of belts giving motion to the dynamo in such a manner as to allow of their regulating the speed of, and, when necessary, reversing the action of the dynamo. The speed he would regulate by passing a belt over two cones, one of them inverted and standing on its apex; so that by raising or lowering it the belt is tightened or loosened on the cones. Above one of these cones, and revolving on the same axis, is a pulley-block, from which the driving-belt passes to the dynamo, and when the motion of the carriage wheels is reversed, a ratchet shifts the position of the pulley, and gives a reversed action to the driving-belt.

Mr. Tommasi, in 1882, proposed a variety of expedients for simply interrupting the revolutions of the dynamo as soon as the motion of the train was reversed. One of these consisted in attaching to the axle of the carriage a small wheel working by friction against a second, over which the driving-belt passed, and arranged so that on the carriage ceasing to advance, or on its motion being reversed, the friction between the two wheels would cease, and the dynamo stop working. By a second plan the same effect was to be produced by the automatic action of a hammer and catch. Mr. Eli Starr, of Philadelphia (1882), proposed to place one wheel on the axle of the carriage, another above it on the axis of the dynamo, and a third between the two which, when pressed against them by the admission of some of the compressed air used with a continuous brake, would cause both to revolve, but would again separate from the other wheels whenever the brake of the train came into use.

Messrs. W. H. Preece and J. James (1882) would give motion to a generating dynamo by means of compressed air continuously provided to a chamber by means of air pumps worked by eccentrics connected with the carriage axles; but the author objects that the clouds of dust raised upon the railway would choke the action of the pumps, and render such an arrangement impracticable.

He is of opinion that all the above described plans are more or less imperfect, and that the requisite regulation of the current could be better effected electrically by using the accumulators for the purpose or by shifting the electrical contacts, than by any mechanical contrivances. Several such arrangements have been proposed by Messrs. Stern and Billingsby, and by Mr. Tommasi and others.

One ingenious plan devised by Messrs. Stern and Billingsby consists in making the dynamo, on its rotation being reversed, cause the positive and negative poles of the circuit to change places; another consists in charging alternately two separate series of accumulators, and at regular intervals using, first the one and then the other for lighting the lamps. Mr. Tommasi obtains a similar result by interposing a resistance varying with the speed at which the dynamo is running, and thus furnishing a substantially constant current to the lamps, whilst the excess only of the current passes into the auxiliary accumulators; and Mr. Calo interposes in the circuit by which the lamps are supplied, a series of accumulators which are acted upon in more or less number according as the speed of the dynamo increases or diminishes. Mr. Tommasi has also more recently advocated the use of a small auxiliary dynamo, which when not required for keeping up the supply of a continuous and sufficient current to the lamps, should be used for maintaining a full charge in the accumulators. It is, however, pointed out by the author that if the action of these dynamos were independent of the movement of the train, there would be no further need for any of these rather complicated arrangements, and that even the accumulators might in that case be dispensed with.—*Abstracts of Institution of Civil Engineers.*

RAIL-TESTING IN RUSSIA—By N. BELELUBSKY.—Since 1878 the Russian Ministry of Ways and Communications has enforced the following conditions for the testing of iron and steel rails.

The whole supply of rails is first to be inspected and their dimensions checked. After the removal of defective rails the rest are to be piled in stacks of 1,000 rails each. From each of these stacks the Government inspector is to choose three rails, from each of which three test pieces six feet in length are to be carefully cut.

Of the three test pieces one is to be subjected to a pressure test and the other two to a striking test. If the testing takes place at a higher temperature than from 0° to 10° Fahrenheit, two at least of the pieces must undergo the striking test reduced to that temperature. The cooling is done by surrounding the rail in a wooden box, 9 feet 4 inches by 3 feet by 2 feet, with a mixture of ice and salt. The temperature of the rail is measured by a thermometer, placed in a hole bored in the end of the rail and filled with mercury.

1, *Test for Bending under Load.*—The piece to be tested is laid on supports 3 feet 6 inches apart, and subjected for five minutes to the

application in the middle of the load A (see Table) when the deflection must be not less than 0.12 inch (3 millimeters) on removal of the load, but the permanent set not more than 0.08 inch (2 millimeters). The weight is to be applied twice, and after the second applicatiou the permanent set must not exceed 0.08 inch.

2. *Bending Test with Increased Load.*—Pieces which have stood the first test are to be subjected to the load B (see Table), which they must support for five minutes without breaking.

3. *Test by Falling Weight.*—The remaining two pieces of the same rails are to be placed on the supports, and after two strokes from a weight of 923.7 lbs. falling from a height H (see Table), must not show any external signs of fracture.

4. *Test of the Goodness of the Material.*—All pieces which have stood the above tests are put under the same hammer, falling from H+1, H+2, &c., feet until they break.

Note.—The testing apparatus is made to a normal pattern, and the site for its erection is chosen by the inspector. The metal base must weigh not less than 19.7 tons, and the bottom of the stone foundations must be not less than 4 feet 6 inches below the surface of the ground.

The following Table gives the values of A, B and H, referred to above, for various weights of normal steel and iron rails:

	Weight per yard.	Load A.	Load B.	Height H.
	Lbs.	Tons	Tons.	Feet.
Steel.....	46.4	9.00	13.92	4.75
	50.4	11.06	16.38	5.65
	54.4	13.10	19.66	6.50
	58 5	15 15	22.52	7.50
	64.5	17.20	25.39	8.50
Wrought iron	54.4	9.00	11.47	4.00
	54.4	11.06	13 51	4.55
	64.5	13.10	16.38	5 25
	70.6	15.15	20.07	6.00

If more than a third of the pieces do not stand the tests all the thousand rails from which they have been taken are rejected, but if a third, or less than a third fail, it is permitted to re-divide the stack of one thousand into lots of two hundred to three hundred, and make the acceptance of these depend upon the tests of at least two rails from each stack.

The putting aside of large quantities of steel rails from year to year, in consequence of breakage or wearing out, suggested to the Imperial Russian Technical Society in St. Petersburg to contribute, by examination of the removed rails, to the discovery of the causes which influence the life of rails; and especially with a view to finding whether the present testing regulations require alteration, and whether harder or softer material is to be preferred for rails. To forward these investigations nearly all the Russian railways sent to the Technical Society a large number of samples of rails and tires, with statistical notes referring to each.

Although these investigations were commenced by the Technical Society as a private undertaking (with, however, the support of the railway management), the work received official recognition in 1884 from the Ministry of Ways and Communications, and the convention of representatives of steel-works and of railway managers called together by this Ministry decided to defer until the conclusion of the first series of investigations the answering of the question whether the regulations for testing and accepting rails which have been in force for the last seven years required to be altered or not? This first series consists in the examination of worn rails and tires. The results will be put together in the graphic form. A further series of investigations is planned, in which steel rails of different degrees of hardness, furnished by Russian steel works, will be laid in and periodically inspected by the commission.

The following are the alterations in the regulations for the acceptance of rails suggested by the Management of the State Railways in conjunction with the Commission of the Imperial Technical Society.

1. In the bending test with load A the maximum permanent set shall be 0.04 inch (1 millimeter), instead of 0.08 inch (2 millimeters), and no demand need be made as to elasticity.

2. The test for bending with increased load B may be omitted.

3. If the temperature of the air is below 9.5° Fahrenheit, no artificial cooling need be applied.

The following is the programme of the investigation now going on:

A. Data to be collected by the railway management: (*a.*) Type of rail, name of works, mark and year, original weight per running foot. (*b.*) Load on the axles of engines running upon the line. Gross tonnage passing over the rails. (*c*) Weight of rail when taken up. Cause of failure: broken (time, place, on or between the cross-sleepers); not broken but worn out. (*d.*) Position of the rail in the line: in straight or on curve (radius, inner or outer line), level or on gradient, quality of ground and ballast. (*e.*) Life of rail.

B. Ministerial tests: Striking and bending, carried out by the Commission at the Putiloff works (St. Petersburg). (*a.*) Bending test: loading in press; deflection, permanent and temporary. (*b.*) Striking test: temperatnre of the tested rail; height of fall of the monkey (1½ ton in weight). Deflection at first and second blow.

C. Tearing test, carried out in the mechanical laboratory of the Road-Construction Engineers Institution. (*a.*) Tensile strength (R), relative extension (*i*), contraction (*c*) at fracture. Product R*i* and sum R+*c*.

D. Torsion test, carried out at same place as C. Limit of elasticity, shearing strength, work at limit of elasticity and at fracture.

E. Quantitative analysis, carried out in the chemical laboratory of the Finance Minister. Percentage of carbon, manganese, silicon, phos-

phorus, sulphur.—*Abstracts of Institution of Civil Engineers,*

RAILWAYS OF EUROPE.—According to a statement in a recent *Revue Generale des Chemins de Fer*, the length of railways open for traffic in Europe, on December 31st, 1884, as compared with the mileage open at the same date in 1883, Germany heads the list with 36,737 kilos. of railway, as against 35,908 kilos. in December, 1883; increase during the year, 829 kilos., or 2.31 per cent. Next follows France with 31,216 kilos., against 29,714 kilos.; increase, 1,502 kilos., or 5.05 per cent. Great Britain and Ireland, 30,514 kilos., against 30,179 kilos.; increase 1.11 per cent. Russia and Finland, 25,391 kilos., against 24,888 kilos.; increase 503 kilos, or 2.02 per cent. Austria, 22,016 kilos., against 20,857 kilos.; increase 1,249 kilos., or 5.99 per cent. Italy, 9,925 kilos., against 9,445 kilos.; increase 470 kilos., or 4.97 per cent. Spain, 8,663 kilos., against 8,251 kilos.; increase 412 kilos., or 4.99 per cent. Sweden and Norway, 8,162 kilos., against 7,960 kilos.; increase 202 kilos., or 2.54 per cent. Belgium, 4.319 kilos., against 4,273 kilos.; increase 46 kilos., or 1.08 per cent. Switzerland, 2,761 kilos., against 2,750 kilos.; increase 11 kilos., or 0.40 per cent. Holland and Luxemburg, 2,654 kilos., against 2,521 kilos.; increase 133 kilos., or 5.28 per cent. Denmark, 1,944 kilos., against 1,813 kilos; increase 131 kilos., or 7.23 per cent. Roumania, 1,602 kilos., against 1,520 kilos.; increase 82 kilos., or 5.39 per cent. Portugal, 1,527 kilos., against 1,494 kilos.; increase 33 kilos., or 221 per cent. Turkey, Bulgaria and Roumelia do not show an increase in the mileage of their railways during 1884, which had a length of 1,394 kilos. in December, 1883; nor do the railways of Servia, with 244 kilos. Greece, on the contrary, increased her railways from 22 kilos. in 1883, to 175 kilos. in 1884. The total length of European railways on December 31st, 1884, was 189,334 kilos., compared with 182,999 kilos. on December 31st, 1883. The aggregate increase was 6,335 kilos., or 3.46 per cent.

ORDNANCE AND NAVAL.

BURMESE ARMS.—Long matchlocks, with very small stocks, are the only Burmese firearms, besides the short, broad cannon used in salutes. The former carry a long distance, and are not fired from the shoulder, but from the side of the head, nearly on a level with the ear. Attached to the small square embroidered bag that every Shan carries over his shoulder, is a small powder-flask of the shape of a miniature horn, flattened and distended at the point, which is open, but has a flat piece of horn which fits into it, and is prolonged backwards across the curve of the flask, to the base of which it is firmly fastened. Downward pressure on the free portion over the curve raises the lid-like anterior extremity of this primitive spring, and allows the powder to run out in driblets. More capacious powder-flasks are made of the horns of cattle, but they are only used on a long expedition. They are suspend from a broad red belt, ornamented with lines and rosettes of cowries, and with tufts of red hair round the margins. The horn of the serrow, artificially sharpened at the point, is usually found attached to the shoulder-bag, and is used as a borer, while its base may be bound with brass, and closed with a lid as a lime or opium box.

A description of the costume of the Shans generally, would be very incomplete were the dáh unnoticed. This has a blade 2½ feet to 3 feet long, gradually expanding from the hilt towards the almost square point, which is about 2½ inches broad. The handle is of wood, bound with cord, and ornamented with silver foil, with a tuft of red goat's hair stuck in the hilt. The wooden scabbard covers only one side of the blade, and a hoop of rattan, bound with red cloth, is attached to its upper third, and worn over the right shoulder.

The Kakhyens have a very ingenious way of striking fire by the sudden and forcible descent of a piston in a closed cylinder. There is a small cup-shaped cavity at the end of the piston-rod into which tinder is inserted. The piston is then introduced into the cylinder, which it tightly fits, and by a blow is made to descend with great rapidity and force, and is as rapidly withdrawn, when the little pellet of tinder is found to have become ignited: a beautiful but simple experiment, illustrating the evolution of a very large amount of heat by the sudden compression of the air in the piston. These instruments are not more than four inches long, and are in general use.

THE STRENGTH OF RIFLED GUNS.—The author deals with the French artillery and its steel guns of the period 1861 to 1870. Guns of above five inches bore only are referred to, as that at this time there was no question of the strength of guns of smaller calibre. After describing the trials of guns of various modes of construction, the author shows that up to 1870, the manufacturers could not deliver steel-blocks from which a safe gun could be constructed.

The second section embraces the period 1872 to 1875, and describes the trial of two guns of 9.44 inches bore, the results of which showed that though great improvements had been made in the manufacture of steel since 1868, still in 1872-3, it was not sufficiently advanced to insure good tubes of all calibres, or jackets for guns of 9.4 inches bore suitable for service, and in fact that the strength of steel guns of that date was not superior to the cast-iron guns of 1870 then in service.

Section iii. treats of the period 1875-81. Refers to the offer of the Creuzot firm to make a steel gun of 100 tons weight, to be placed in the Paris Exhibition of 1878, and purchased by the French Government at 2s. 8½d. per lb., and after trial, an order for ten more to be given at 1s. 11d. per lb. General Frébault's protest against the proposal is quoted at length, with his offer to construct a gun of equal strength, of cast-iron tubed and hooped, at a cost of 5.45d. per lb. Though the Creuzot offer was not accepted, it was decided from that date —1875—to make all the large guns of the fleet of steel.

The trials and mode of construction of vari-

ous guns of from 10.6 inches to 16.5 inches bore are described. The latter was only delivered in 1882, as the Compagnie Forges de St. Chamond were obliged to erect an 80-ton steam-hammer to enable them to make the gun. The author considers that up to the time of the erection of this hammer, and the trial of the 16.5 inch gun, the introduction of steel had increased the cost of guns threefold, without any increase in ballistic effects. The armament of the fleet was retarded several years, and to avoid risks, unusual precautions, which were superfluous for iron guns, had to be taken.

Section iv. gives the period 1881–5 with few details, but notes the improvements in quality and regularity of the steel supplied by French firms, draws comparisons between the comparatively small bores of 1881, and the larger bores of 1875–9, also the lengths of the guns; concluding with the statement that as regards steel guns the French artillery is in a state of advancement and certainty whilst foreign countries are in an experimental stage.

Passing on to foreign countries and giving a *resume* of the histories of the Whitworth and Krupp systems (the former only to 1876), he divides the latter into five periods—1851–68, 1869–72, 1872–77, 1879–82, 1882–85. The principal trials and manufactures of these periods are noted, the information being drawn from numerous sources, principally the Prussian Government trials. The introduction of the brown cocoa powders is here noticed, and the consequent reduction in pressure as compared with the old iron guns.

Referring to foreign nations, nearly all of which, whilst recognizing and using steel, have no definite models for their artillery. England is stated to be in a transition state, reference is made to the report of the 1883-4 United States Committee on the Elswick works, and the bulk of this section is taken up with extracts from and remarks on Colonel Maitland's paper read read at the United Service Institution on the 20th of June, 1884. Italy is next taken, and the large guns made by Armstrong are described and criticised.

Russia, at the time of writing, was only in an experimental stage, also the United States.

The Gonzalez Hontoria guns of the Spanish navy are described and illustrated.

The period of guns made with coils of wrought iron is reviewed, and the bursting of the 38-ton Woolwich, 100-ton Armstrong, and 6-inch "Active" guns are discussed.

In the last chapter, guns on various systems are noticed, including bronze, wrought iron, Longridge, Hope and Ordoner guns. These are noted, not because of results of extended trials, "but because they indicate new lines of experiments, abandoned ideas, or more or less beaten tracks which lead to no issue, and should be avoided." In conclusion, the author enforces the opinion that in artillery matters, the best text-books are of no value; but that practical and continued trials are the only lines on which it is safe to rely.—*Abstracts of Institution of Civil Engineers.*

BOOK NOTICES.

Publications Received.

Report of the Commissioner of Navigation for 1885. Washington: Government Printing Office.

Manufacture, Consumption and Production of Iron, Steel, and Coal in the Dominion of Canada. By James Herbert Bartlett. Montreal: Dawson Brothers.

Annual Report of the State Geologist of New York, for the year 1885. Trenton: John S. Murphy.

Sanitary Engineering. By William Cain, C.E., Raleigh, N. C.: P. M. Hale.

The Manufacture, Consumption and Production of Iron, Steel and Coal in the Dominion of Canada. By James Herbert Bartlett. Montreal: Dawson Brothers.

This work is mainly statistical, but as it records the history of the beginnings of some important industries it will be found interesting.

The history of the first iron works in Canada, the St. Maurice Forges, is first concisely sketched, and is followed by brief accounts of other works in the Province of Quebec.

Early enterprises in Ontario form the subject of Chapter III.

Chapter IV. deals with smelting in New Brunswick, and Chapter V. with the manufacture of iron in Nova Scotia.

A general account of the iron trade in other countries is given as a concluding chapter, and is added to enforce the idea that the further development of these industries is of the greatest importance to the Dominion.

The Theory of Equations. By William Snow Burnside, M.A., and Arthur William Panton, M.A. Second edition. London: Longmans, Green & Co.

The earlier edition of this work is familiar to most advanced students of pure mathematics. The present edition differs chiefly in the expansion of certain chapters, which, bearing the same titles as before, are considerably enlarged. Chapter XI., Determinants; and Chapter XVI. on Transformations, exhibit the most marked changes.

The entire list of chapter headings is: General Properties of Polynomials, General Properties of Equations, Relations between the Roots and Coefficients of Equations, Transformation of Equations, Solution of Reciprocal and Binomial Equations, Algebraic Solution of the Cubic and Biquadratic, Properties of the Derived Functions, Limits of the Roots of Equations, Separation of the Roots of Equations, Determinants, Symmetric Functions of the Roots, Elimination, Covariants and Invariants, Covariants and Invariants of the Quadratic, Cubic and Quartic Transformations, The Complex Variable.

Electro-Deposition. A Practical Treatise on the electrolysis of Gold, Silver, Copper, Nickel, and other Metals and Alloys. With Several Chapters on Electro-metallurgy. By Alexander Watt. London: Crosby Lockwood & Co. 1886.

This closely printed manual of 500 pages, with numerons illustrations, gives detailed information on the subjects treated of. The author is evidently an expert in a majority of the processes, and, when not so, gives descriptions, generally verbatim, from original authorities. The work contains accounts of the most recent processes, and, especially in the chapters on metallurgy, will be found both interesting and instructive. Smelting and refining by electricity is in the case of many metals—gold, silver, copper, lead, zinc—superseding the older and rougher methods. The gain in economy from cheapness of plant, chemical purity of product, profitable disposal of by-products, as well as safety and improved hygienic surroundings of the operators, recommend them highly; besides this, to them we owe our present supplies of the new alloys of alluminium and silicon bronzes. The chemistry of the different processes is satisfactorily explained. There is also given a brief account of the modes of developing the current, beginning with the original contrivances of Volta, the several chemical batteries, the magneto-electric machine, the dynamo, and, finally, thermo-electric piles. The descriptions of these machines may probably be found satisfactory to amateurs and workmen. Scientific men will observe many defects, and we think much of this matter might with propriety have been omitted. In thermo-electricity we think the author does good service in emphasising the immense possibilities lying hid therein. In no work have we seen this field of practical science so truly estimated, as undoubtedly the most theoretically perfect mode of collecting for mechanical uses the very elusive molecular forces of heat. The book also gives a brief account of the history of the art, and in interesting quotations from contemporaneous journals affords a glimpse of the excitement aroused by the announcement of the discovery of the successive processes which have now become so familiar and commonplace—such excitement as the older of the present generation may remember some years later caused by the discoveries of Talbot and Niepce in photography, or more recently those of Edison, Varley and Bell in the phonograph and telephone.—*Iron.*

This book opens with three historical chapters, giving an account of the rise and progress of Voltaic electricity—without mention of the anticipation of Galvani's initial experiment by the illustrious Dutch naturalist, Swammerdam—of electro-magnetism, magno-electricity, dynamo-electricity, and thermo-electricity, which latter Mr. Watt believes has before it a great future, the thermo-pile being the only example of the direct conversion of heat into electric energy, and as far as is known this is generated without any other waste beyond that of the fuel consumed in generating the heat necessary.

The fourth chapter gives from original sources, the history of electro-deposition. Our readers will doubtless be surprised to learn that the earliest successful experiments were made by Sir H. Bessemer when a youth of eighteen, anticipating Jacobi by about seven years, and that Jordan was the first to publish a definite process.

In the fifth chapter we find a theory of electrolysis, whilst in the following section there is an examination of electrical theories in their relation to the deposition of metals. The processes for coppering, gilding, and silvering are next expounded with great minuteness.

The electro-deposition of nickel, tin, iron, zinc, and some of the metals less generally used is next considered, followed by instructions for the deposition of alloys, such as brass, bronze, and German silver.

We have then three chapters on electro-metallurgy, under which head rank processes for refining copper and lead; for the electrolytic refining of gold, silver, and copper ores, and for the electro-chlorination of gold ores.

In conclusion follow chapters on some mechanical operations subsidiary to electro-deposition, on the recovery of the precious metals from waste solutions, and on stripping metals from each other.

A separate chapter is devoted to the consideration of the chemical agents used in the electro-plastic art.

Under the heading "Useful Information" Mr. Watt gives hints on the management of batteries, their relative power, intensity, and constancy; tests for free cyanide, and remedies in case of poisoning. Such information is exceedingly valuable to all persons obliged to manipulate so formidable a poison as potassium-cyanide. Accidents from this substance are not unfrequent in electro-plating works. Indeed, the author confesses to having been three times placed in some danger by swallowing a solution of cyanide, or inhaling its fumes. He recommends that the coldest water procurable should be poured upon the head and allowed to run down the spine of the sufferer, whilst ammonia or bleaching lime is cautiously applied to the nostrils. He even recommends that this acid should never be used without a second person holding a phial of one of these agents near the nose of the operator. We should recommend as a more excellent way to hold the breath entirely whilst pouring out hydrocyanic acid from a bottle, or never to work with it except under a good draught-hood.

Mr. Watt's work will be very serviceable to technical students, to apprentices, workmen who are seeking to qualify themselves for more responsible positions, and, if we may venture to say so, to manufacturers who feel the necessity of discarding rule-of-thumb and combining in future practice with theory.—*Chemical News.*

MISCELLANEOUS.

An Asian California.—A letter from St. Petersburg in the *Journal des Debats* gives a description of the new California, as the new gold mines discovered in the valley of the Djolgute River are called. This valley is upon the Chinese bank of the Amoor, opposite the Russian Colony of Tgnachino, and as the soil is very marshy, and there are no roads, it is only accessible in winter. Gold was first dis-

covered there in May, 1884, and it soon attracted a great many adventurers, the earliest comers being Russian deserters and escaped convicts from Siberia, and by the month of January in last year there was a colony of 9,000 Russians, the total having been very much increased since, while there are also about 6,000 Chinese and 150 adventurers of different nationalities, the last-named of whom have joined the Russians, the organization of the colony being altogether Russian. The gold-finders are divided into 722 artels (small groups) of workmen, all of whom are absolutely equal. These artels elect twelve elders (starchina), who do not work themselves, but superintend the diggings, and receive a salary of 200 roubles a month. They are selected from among the dealers in gold and tavern keepers, and form a sort of district police corps. They do not meet with any interference from the Chinese authorities in this remote valley, the laws of which are very simple but severe, the penalty of death being inflicted for cheating at play, for adulterating the gold dust, or for theft; while flogging is inflicted for drunkenness during the hours of labor or for bringing females into the colony. Since the foundation of the colony there have been only three murders and two inflictions of the death penalty, a Russian having been hung for adulterating the gold dust, and a Jew flogged to death for having spread false news as to the approach of a body of Russian troops, hoping thereby to send down the price of gold, owing to the panic. There are twenty-seven taverns in the colony, and, owing to the competition, the prices are not high, except for spirits. The gold-fields, which are 25 miles in length by 3 miles broad, are said to be very rich, and 7 lbs. of gold are obtained from 32 cwt. of gravel, even with the primitive mode of washing adopted there.

LIQUID FUEL FOR STEAMSHIPS.—The system of oil-burning apparatus recently described by us as having been fitted on board the Himalaya steamship has been applied to a vessel recently launched by Messrs. Wigham, Richardson & Co., of Newcastle-on-Tyne. The steamer, which is intended for the Black Sea trade, and to be permanently oil-burning, has her water-ballast tanks divided up, and made available for the storage of her fuel. She has also other storage tanks built into the ship on each side of the engine-room, all these being connected by pipes to the small feed-tanks situated above the boiler. A large supply pipe connected through valves to the storage tanks allows of the vessel being filled up with fuel in a very short space of time. The oil-burning apparatus has been fitted by the Tarbutt Liquid Fuel Company, of 75 Lombard Street, London, and is similar to that adopted on board the Himalaya, which recently made her successful trial trip from London to Granton and back on the new fuel. A trial of the apparatus has just been satisfactorily completed at Messrs. Wigham, Richardson & Co.'s works, which was attended by representatives from some of the leading shipbuilding and engineering works on the Tyne, who are evincing great interest in this most recent development of the liquid fuel question. A number of applications of this system are now being made to marine and stationary boilers, stills, and plate-heating furnaces.—*The London Times.*

METAL WORK OF THE BURMESE.—Both Burmans and Shans are expert blacksmiths. The latter forge all the *dahs* (native hatchets) used by themselves and their neighbors in the Hotha valley, and they annually resort to Bhamo, and the villages in the Kakhyen hills, for the purpose of manufacturing them. Their bellows are of the most primitive stamp, consisting of two segments of bamboo, about 4 inches in diameter and 5 feet long, set vertically, forming the cylinders, which are open above and closed below, except by two small bamboo tubes, which converge and meet at the fire. Each piston consists of a bunch of feathers, or other soft substance, which expands and fits tightly in the cylinder while it is being forcibly driven down, and collapses to let the air pass as it is being drawn up. A boy, perched on a high seat or stand, works the two pistons alternately, by the sticks serving as piston rods. Charcoal is used for fuel.

The casting of large and small articles in brass, bronze, and other alloys is much practiced, always adopting the method known as *à cire perdue*. First, a clay model is made, and coated with beeswax to the thickness of the intended cast, and again covered with an outer skin (2 inches thick) of clay, mixed with finely-chopped straw; this latter coat is provided with funnel-like holes, for pouring in the molten metal, at intervals of 4 inches, and with straw-holes for letting out imprisoned air. Holes are also provided at the bottom for the escape of the melted wax.

A NEW sweetening agent has been produced from coal-tar. It is known to chemists as "benzoyl sulphuric imide," but it is proposed to name it "saccharine." The discoverer is Dr. Fahlberg, a German chemist in America, and its preparation and properties were recently described by Mr Ivan Levinstein at a meeting of the Manchester Section of the Society of Chemical industry. Saccharine presents the appearance of a white powder, and crystalizes from its aqueous solution in thick short prisms, which are with difficulty soluble in cold water, but more easily in warm. Alcohol, ether, glucose, glycerol, &c., are good solvents of saccharine. It melts at 200 deg. Cent., with partial decomposition; its taste in diluted solutions is intensely sweet, so much so that one part will give a very sweet taste to 10,000 parts of water. Saccharine forms salts, all of which possess a powerful saccharine taste; it is endowed with moderately strong antiseptic properties, and is not decomposed in the human system, but eliminated from the body without undergoing any change. It is about 230 times sweeter than the best cane or beetroot sugar. The use of saccharine will therefore be not merely as a probable substitute for sugar, but it may even be applied to medicinal purposes where sugar is not permissible. One part of saccharine added to 1,000 parts of glucose forms a mixture quite as sweet as ordinary cane sugar. The present price is 50s. per pound; but

although very high, this is not prohibitory, as its sweetening power is so great; but it is very probable the cost of its manufacture will soon be very considerably reduced. The *Brewers' Guardian* says: "This new compound will be of great interest to brewers, for not only is it perfectly wholesome, but it possesses, in addition to its intensely sweet taste, decided antiseptic properties, and therefore may be usefully, safely, and advantageously added to beer."

CARBONIC ACID IN THE LIQUID AND THE SOLID STATE.—The employment of liquefied carbonic acid gas for various manufacturing operations has resulted in the development of a new industry. For many years after Davy and Faraday had succeeded in effecting the liquifaction of this gas, and even after Natterer, of Vienna, had devised a special apparatus for the purpose, the process was regarded merely in the light of a lecture experiment, and was only usefully employed for the production of very low temperatures The author first turned his attention to the subject in connection with the plans for raising the armor-clad ship, the Grosser Kurfürst in 1878. His first practical experiment in this direction was carried out at Kiel in 1879, when, by means of about 40 kilograms of liquid carbonic acid enclosed in a receiver, to which was attached an empty balloon formed of sail-cloth coated with india-rubber, a block of stone weighing 316 centners (16 tons) was raised to the surface in eight minutes after the tap opening the communication from the receiver to the balloon was turned by a diver. The success of this experiment led to the proposal to found a company for the raising of sunken vessels on this system, but the scheme came to nothing, partly because of the difficulty at that time of producing the liquid in large quantities at a cheap rate.

Subsequently, Mr. F. A. Krupp, of Essen, used this fluid for the production of low temperatures for shrinking out the cores of cannons, and for the compression of molten metal in the molds. He obtained in this way a pressure of 75 atmospheres, and was able to produce much more solid and dense castings than before. In consequence of the steady improvement in the pumping apparatus employed at Essen for the compression of the gas, and the production of the liquid in large quantities, it became possible, owing to its cheapness, to make use of it for beer-raising and in the manufacture of artificial mineral waters.

In process of time the firm of Kunheim & Company, of Berlin, took the matter in hand and turned the scientific facts to industrial account. Their business was taken over by the Berlin Company for the Carbonic-Acid manufacture, which has been most successful, and now produces daily eighty cylinders, each containing 8 kilograms, or 640 kilograms (1,411 lbs.) of liquid carbonic acid, equal to 320,000 litres of gas.

This is employed for beer-raising in the same way as compressed air was formerly made use of. The cylinder of liquid is attached to a receiver, and on turning the tap connecting the two vessels the liquid rushes in, and expands in so doing into the gaseous form. In a few seconds this gas attains a pressure in the larger vessel of 1½ atmosphere, and the tap is then closed. The pipes conducting to the beer casks are subsequently opened, and the carbonic acid gas flows into the casks with a pressure sufficient for the drawing off of the beer. As only pure carbonic acid gas passes into the beer-casks all putrefactive processes are avoided, and the beer is drawn in a bright and sparkling condition. Eight kilograms of the compressed gas are sufficient for the delivery of 24 to 30 hectolitres of beer.

The pressure exerted by liquid carbonic acid varies in accordance with the temperature; thus:

		atmosphere.
at −79°	Centigrade the pressure	= 1.2
" −10°	" "	=27.5
" + 5°	" "	=40.5
" +20°	" "	=58.8
" +30°	" "	=73.0

All danger in the storage of the compressed gas is avoided by the testing of the cylinders (which are made of wrought iron) to 250 atmospheres before they are filled, and the receivers are furnished with a safety-valve, weighted to a little over 1½ atmosphere pressure, and these are all tested to 5 atmospheres. Although between six and seven thousand cylinders of the liquefied gas have been sent out, and have been used for the most part by unskilled persons, there have been no accidents of any kind The price of a cylinder of the liquid is 16 marks (16s).

By removing the pressure or allowing the liquefied gas to escape into a woolen bag an intense cold is produced, and a sufficient amount of heat is abstracted to cause a portion of the remaining liquid to freeze into crystals, resembling snow. These frozen needles can be brought, by means of slight pressure, into solid lumps resembling chalk, which are specifically heavier than water, and which by increased pressure can be obtained of a specific gravity of 1.5. By surrounding this solidified carbonic acid with a bad conductor it may be preserved for as much as fifteen hours, during which time it is, of course, being gradually dispersed in the gaseous form.—*Abstracts of Institution of Civil Engineers.*

AT the Edinburgh (Scotland) International Exhibition, which is to be opened in May and continue till October, the manufacturers of Sheffield are to be worthily represented. An Exhibitors' Committee has been formed, and many of the most skilled artisans of the town have responded to the invitation to exhibit, with the result that in many departments there will be a capital show of Sheffield's high-class work. A good position—what the Committee consider the most prominent and best position in the artisan section of the Exhibition—has been secured for the Sheffield workmen. It is intended to have examples of old Sheffield work placed side by side with the specimens of skill made by modern artisans.—*The Engineer.*